Fishery Data Series No. 14-21

Sonar Estimation of Salmon Passage in the Yukon River near Pilot Station, 2011

by

Jody D. Lozori

and

Bruce C. McIntosh

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures) first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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By
Jody D. Lozori and Bruce C. McIntosh
Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Jody D. Lozori,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Rd., Fairbanks, AK 99701, USA

and

Bruce C. McIntosh,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Rd., Fairbanks, AK 99701, USA

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ABSTRACT

The Pilot Station sonar project has provided daily passage estimates for Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, and coho salmon *O. kisutch* for most years since 1986. Fish passage estimates for each species were generated in 2011 through a 2-component process: (1) estimation of total fish passage with 120 kHz split-beam sonar and a dual-frequency identification sonar (DIDSON), and (2) apportionment to species by sampling with a suite of gillnets of various mesh sizes. An estimated 3,691,528 fish passed through the sonar sampling area between June 1 and September 7, 1,145,720 along the right bank and 2,545,808 along the left bank. Included were 100,217 ± 17,044 large Chinook salmon (>655 mm mideye tail fork), 23,152 ± 5,521 small Chinook salmon (≤655 mm mideye tail fork), 1,977,808 ± 81,643 summer chum salmon, 764,194 ± 50,063 fall chum salmon; and 124,931 ± 21,287 coho salmon.

Key words: Yukon River, Chinook salmon, *Oncorhynchus tshawytscha*, chum salmon, *Oncorhynchus keta*, hydroacoustic, riverine, sonar, run strength, species apportionment, net selectivity, DIDSON.

INTRODUCTION

BACKGROUND

Within Alaska, 3 species of Pacific salmon (Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and chum salmon *O. keta*) are managed inseason for harvest by commercial, sport, and subsistence fisheries over 2,200 km of the Yukon River, as well as to meet treaty commitments made under the U.S./Canada Yukon River Salmon Agreement (Yukon River Panel 2004). The diversity and number of fish stocks, combined with the geographic range of user groups, adds complexity to management decisions. Escapement estimates and run-strength indices are generated by various projects along the river, providing stock-specific abundance and timing information. However, much of this information is obtained after the fish have become unavailable to the fisheries. Timely indices of run strength are provided by gillnet test fisheries conducted in the lower Yukon River, but the functional relationship between catch per unit effort (CPUE) and actual abundance is confounded by varying migration patterns through the multi-channel environment, gear selectivity, environmental conditions, and changes in net site characteristics.

The Pilot Station sonar project has provided daily salmon passage estimates, run timing, and biological information to fisheries managers for most years since 1986. The estimates from this project complement information obtained from other sources. Located in a single-channel environment at river km 197 near Pilot Station, the project is far enough upriver to avoid the wide, multiple channels of the Yukon River Delta. Because salmon migrate from the river mouth to the sonar site in 2 to 3 days, the project provides timely abundance information to managers of downstream fisheries (Figure 1). The Andreafsky River is the only significant salmon spawning tributary downstream of the sonar site (Figure 2), therefore the majority of migrating salmon in the Yukon River pass the sonar project on their way to the spawning grounds.

The Alaska Department of Fish and Game's (ADF&G) primary role is to manage for sustained yield under Article VIII of the Alaska Constitution, but Alaska is also obligated to manage Yukon River salmon stocks according to precautionary, abundance-based harvest-sharing principals set forth in the Yukon River Salmon Agreement (Yukon River Panel 2004). The goal of bi-national, coordinated management of Chinook and chum salmon stocks is to meet escapement requirements that will ensure sufficient fish availability for sustained harvests in both the United States and Canada in the future. Furthermore, managers follow guidelines specified in state regulations as management plans for Yukon River Chinook, summer chum, fall chum, and coho salmon. Accurate daily salmon abundance estimates not only help managers regulate fishing inseason to meet harvest and escapement objectives, they are also used postseason to determine whether treaty obligations were met and to judge effects of management actions.

Locations in this report are referenced by the proximate bank of the Yukon River, relative to a downstream perspective. At the sonar site the left bank is south of the right bank. Both the City of Pilot Station and the ADF&G sonar camp are located on the right bank.

Prior to 1993, ADF&G used dual-beam sonar equipment that operated at 420 kHz. For the 1993 season, ADF&G changed the existing sonar equipment to operate at a frequency of 120 kHz to allow greater ensonification range by reducing signal loss. The newly configured equipment's performance was verified using standard acoustic targets in the field. Use of lower frequency equipment increased fish detection at longer ranges.

Up until 1995, ADF&G attempted to identify direction of travel of detected targets by aiming the acoustic beam at an upstream or downstream oblique angle relative to fish travel. This technique was discontinued in 1995 in favor of aiming transducers perpendicular to fish travel to maximize fish detection (Maxwell et al. 1997). Because of this and subsequent changes in counting methodology, data collected from 1995 through 2011 are not directly comparable to previous years. In 2001, the equipment was changed from dual-beam to the current split-beam sonar system configured to operate at 120 kHz (Pfisterer 2002). This system is similar to the split-beam used on the Kenai River during 2008 and 2009, although the Kenai River sonar operated at 200 kHz (Miller et al. 2012). Reference to use of dual-beam sonar at the Pilot Station sonar project can be found in the *Yukon River project report, 2000* (Rich 2001). The split-beam technology allows testing of assumptions about direction of travel and vertical distribution as the target moves through the acoustic beam through the ability to estimate the 3-dimensional position of a target in space (Burwen et al. 1995).

The project uses a combination of fixed-location split-beam sonar and multi-beam dual-frequency identification sonar (DIDSON[1]; Belcher et al. 2002) to estimate the daily upstream passage of fish. A series of gillnets with different mesh sizes are drifted through the acoustic sampling areas to apportion the passage estimates to species. In 2004, the selectivity model used in species apportionment was refined through biometric review and analysis of historical catch data from the project test fishery. The model providing the best overall fit to the data was a Pearson model with a tangle parameter. Species proportions and passage estimates reported here were generated with this apportionment model, and are comparable with estimates from 1995 to the present, as historical estimates have been regenerated using the most current model and methodology (Bromaghin 2004).

Early in the 2005 season, the Yukon River experienced high water levels and erosion in the bottom profile on the left bank. The erosion limited detection in the narrow nearshore portion of the sonar beam by allowing fish to swim under the beam and caused silt plumes that attenuated the sonar signal. Along with a combination of increased nearshore fish distribution, the high water affected detection of fish with the split-beam sonar within 20 m of shore on the left bank. On 19 June 2005, a DIDSON imaging sonar was deployed in this area to verify nearshore fish detection. With its wider beam angle, video-like images, and software algorithms that can

[1] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

remove bottom structure from the image, the DIDSON system was able to detect fish passage within 20 m despite high water levels and problematic erosion nearshore, and was operated for the remainder of the season, supplanting split-beam counts in this section of nearshore region. DIDSON has been used in the Anvik and Sheenjek rivers to give daily passage estimates where bottom profile and river width are appropriate for the wider beam angle and shorter range capabilities of this sonar (McEwen 2010; Dunbar 2012). Since 2006, the DIDSON has been integrated into the sampling routine on the left bank, operating side-by-side with the split-beam sonar. The DIDSON samples the first 20 m of the nearshore stratum with the remainder of the range sampled by the split beam.

During the 2008 season, ADF&G implemented a feasibility study to validate a complete switch from paper charts to electronic echograms for enumerating fish traces (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication). The electronic charts were found to provide a number of advantages that include increased number of threshold levels, better consistency (no ribbons that fade), less downtime related to paper jams, and the ability to easily determine direction of travel. In 2009, electronic echograms replaced paper charts for counting fish traces (Lozori and McIntosh 2013).

The Pilot Station sonar project provides timely and accurate information to Yukon River fishery managers. DIDSON and split-beam sonars were used to collect fish passage estimates. A gillnet test fishery was used to collect age, sex, and length (ASL) and genetic data, as well as data for species apportionment. This report presents data collected in 2011, and compares the results to previous years.

STUDY AREA

The study site is located approximately 1.6 km upstream of the village of Pilot Station (Figure 3). The Yukon River, at the sonar site, is approximately 1,000 m wide between the left and right bank transducers. The left bank substrate, composed of silt and fine sand, drops off gradually at a vertical angle of approximately 2° to 4°. The right bank has a stable, rocky bottom that drops off uniformly to the thalweg at a vertical angle of approximately 10°. The thalweg is approximately 25 m deep and is located approximately 200 m offshore of the right bank.

The Yukon River Basin is the fourth largest basin in North America with a drainage area of 857,300 km^2 and an average annual discharge of 6,400 m^3/s. Flows are highest in June, with greatest variability in flow occurring in May, after which discharge and the variability in discharge decline. The Yukon River is turbid and silty in the summer and fall with an estimated annual suspended sediment load at Pilot Station of 60,000,000 tons (Brabets et al. 2000).

River height, as observed from 2001 to 2010 at the United States Geological Survey (USGS) gaging station located downstream of the project, has ranged from a maximum of 27.4 ft to a minimum of 13.6 ft from June 1 through September 7 (Figure 4).

OBJECTIVES

The primary goal of this project was to accurately estimate daily fish passage, by species, during upstream migration past the sonar site. Project objectives were to:

1. Provide managers with timely estimates, and associated confidence intervals, of daily and seasonal passage of adult Chinook, chum and coho salmon;
2. Collect biological data from all fish captured in the test fishery, including species, sex, length, and scales as appropriate;
3. Assist in the collection of Chinook and chum salmon tissue samples for separate genetic stock identification projects; and
4. Collect water temperature data representative of the ensonified areas of the river.

METHODS

Estimates of upstream migration of targeted fish species were produced from a combination of independently generated estimates of fish movements past the sonar site using hydroacoustic equipment, and species proportions based upon the results of drift gillnetting in the same area (Figure 5).

HYDROACOUSTIC DATA ACQUISITION

Equipment

Left bank sonar equipment included

1. a Hydroacoustic Technology Inc. (HTI) Model 244 echosounder configured to transmit and receive at 120 kHz, controlled via Digital Echo Processing (DEP) software installed on a laptop PC,
2. an HTI 120 kHz split-beam transducer with a 2.8°x10° nominal beam width,
3. three 250 ft (228.6 m combined length) HTI split-beam transducer cables connecting the sounder to the transducer,
4. a Hewlett-Packard (HP) Model 54501A digital storage oscilloscope,
5. a DIDSON-LR (Long Range) unit (14ºx29º nominal beam dimension), configured to transmit and receive at 1.2 MHz, and controlled via software installed on a laptop PC, and
6. one 500 ft DIDSON underwater cable connecting the DIDSON to the “topside breakout box” and laptop PC.

Right bank sonar equipment included

1. an HTI Model 244 echosounder configured to operate at 120 kHz, controlled via DEP software installed on a laptop PC,
2. an HTI split-beam 120 kHz transducer with a 6°x10° nominal beam width,
3. three 250 ft (228.6 m combined length) HTI split-beam cables connecting the sounder to the transducer.

Each HTI system configuration of sounder, transducer, and cable was calibrated by the manufacturer prior to the field season. Transducers were mounted on metal tripods and remotely aimed with HTI model 662H dual-axis rotators. Rotator movements were controlled with HTI model 660-2 rotator controllers with position feedback to the nearest 0.1°. Data were stored on a portable hard drive and transferred to an external RAID storage system. Gasoline generators (3000 W) supplied 120 VAC power.

Equipment Settings and Thresholds

The split-beam echosounders used a 40 log(R) time-varied gain (TVG) and 0.4 ms transmit pulse duration during all sampling activities (Table 1). The receiver bandwidth was automatically determined by the equipment based on the transmit pulse duration. On the left bank, the nearshore stratum pulse repetition rate was set to 5 pings per second (pps), the midshore stratum was set at 3 pps, and the offshore stratum was set at 1.3 pps. The pulse repetition rate for the right bank nearshore was set at 5 pps, and the offshore stratum was set at 3 pps. Because of a high amount of signal attenuation on the left bank, the split-beam threshold setting ranged from -43db to -70db depending on the signal loss at the time A -43db setting is considered optimal because the theoretical on-axis target strength of a 450 mm chum salmon is approximately -32 dB (Love 1977) and 10 dB lower allows detection of a fish this size over the nominal beam. The DIDSON (Table 2) operated at an average rate of 8 frames with a starting range of 0.83 m and an end range of 20.84 m, in high-frequency mode (1.2 MHz).

Aiming

Transducers were deployed on both the left and right banks in an area where the river is approximately 1,000 m wide. The transducers were always positioned and aimed to maximize fish detection. With the transducer located in the area with the best bottom profile, the beam was oriented approximately perpendicular to the current so that migrating fish would present the largest possible reflective surface. Since many fish travel close to the substrate, the maximum response angle of the beam was oriented along the river bottom through as much of the range as possible. The right bank transducer was positioned approximately 3 m from shore, adjusting the aim between 2 strata (S1, 0–50 m; and S2, 50–150 m). The left bank split-beam transducer was positioned as close to shore as possible depending on water height, and utilized 3 distinct aims to sample a nearshore stratum (S3; 0–50 m), a midshore stratum (S4; 50–150 m), and an offshore stratum (S5; 150–300 m). The DIDSON was normally deployed within 2 m of the split-beam transducer and ensonified the first 2 sectors of the nearshore stratum (S3; 0–20 m) (Figure 6). The DIDSON’s wider beam angle should detect close fish targets better than the split beam, which is narrower in the extreme nearshore. Therefore, when aiming the split beam for the nearshore stratum from 0 to 50 m, when necessary for best detection, the aim is optimized for the 20 to 50 m portion of the stratum, which is not ensonified by the DIDSON. In this way, the sonar systems are used in concert to maximize detection for the entire nearshore stratum on the left bank. The counts from the 2 systems cannot directly be compared for the 0 to 20 m nearshore, because the aiming strategy optimizes fish detection for DIDSON but not the split beam within this range.

Fluctuating water levels required repositioning of the transducers and subsequent re-aiming of the transducers. To establish an optimal aim, the transducer was panned horizontally upstream and downstream approximately 15° off perpendicular in 2° increments. At each increment, the vertical tilt was adjusted to obtain the best possible bottom picture using an oscilloscope to confirm that the sonar beam was skimming the substrate. The left bank transducers were re-aimed more often to compensate for the dynamic bottom conditions and continual morphological changes associated with the bank. Once an optimal aim was obtained, the rotator settings were documented and screen captures of echograms made available for visual reference.

Sampling Procedures

Acoustic sampling was conducted simultaneously on both banks during three 3 h periods each day (Table 3). Sample periods were scheduled from 0530 to 0830, 1330 to 1630, and 2130 to 0030 hours, alternating sequentially between strata every 30 minutes. In stratum S3 the DIDSON-generated sonar counts supplanted those of the split beam in the range the systems overlapped if they were higher.

Operators counted fish traces for both the split-beam and the DIDSON system on electronic echograms using Echotastic software. All personnel were trained to distinguish between fish traces and non-target echoes. Echo traces were counted as a single fish if at least 2 pings in the cluster passed the threshold level (see *Equipment Settings and Thresholds* section) and the targets did not resemble inert downstream objects. Valid downstream fish targets were retained and adjusted into the total estimate of fish passage for consistency with historical methodology. Groups of fish were distinguishable when the apparent direction of movement of a single fish trace differed from that of an adjacent trace.

Echograms were reviewed daily by either the project leader or crew leader to monitor the accuracy of the marked fish tracings and reduce individual biases. Each echogram was checked for indications of signal loss and changes in bottom reverberation markings, which could indicate either movement of the transducer or a change in bottom profile.

Fish traces were tallied on electronic echograms. The data was checked daily for data entry or tallying errors, then processed in statistical software (SAS®) using routines developed by the regional biometrician.

SYSTEM ANALYSES

Performance of the split-beam hydroacoustic system was routinely monitored following procedures first established in 1995 (Maxwell et al. 1997). Monitoring of the DIDSON included daily checks of sonar settings prior to each sampling period, routine checks of water height near pod, checking aim settings, as well as monthly cleaning of the transducer lens. System analyses included equipment performance checks, bottom profiles using down-looking sonar, and hydrologic measurements.

Bottom Profiles

Bottom profiles were recorded along both banks using a Lowrance LCX15MT recording fathometer with GPS capabilities to locate deployment sites with suitable linear bottom profiles. All bottom profiles were recorded and stored electronically. Inseason, the fathometer was used regularly to monitor changing bottom conditions and to watch for the formation of sandbars capable of re-routing fish to unensonified areas.

Hydrological Measurements

Water level was measured using a staff gage located slightly offshore on the right bank near the field camp. To standardize measurements with observations from previous years, water level measurements were adjusted to the USGS Water Resources Division reference located approximately 500 m downstream of Pilot Station. The information collected from the staff gage was used inseason as a relative water height indicator, and to gather information as a backup for times when the USGS water data was unavailable.

Electronic data loggers were deployed on the left bank on June 3 and on right bank on May 29. Both loggers remained submerged until September 7 (Figure 7).

SPECIES APPORTIONMENT

Equipment and Procedures

To estimate species composition, gillnets were drifted through 3 zones (right bank, left bank nearshore, and left bank offshore) corresponding to sonar sampling strata (Figure 6). A total of 8 different mesh sizes were fished throughout the season to effectively capture all size classes of fish present and detectable by the hydroacoustic equipment (Table 4). All nets were 25 fathoms (45.7 m) long and approximately 8 m deep. All nets were constructed of shade 11, double knot multifilament nylon twine and hung "even" at a 21 ratio of web to corkline.

Test fishing was conducted twice daily between sonar periods, from 0900 to 1200 hours and 1700 to 2000 hours. During each sampling period, 4 different nets were drifted within each of 3 zones for a total of 24 drifts per day (Table 5). The order of drifts were 1) left bank nearshore zone, 2) right bank zone, and 3) left bank offshore zone, with a minimum of 20 minutes between drifts in the same zone. Each mesh size was fished in all 3 zones before switching to the next mesh size. The shoreward end of the left bank nearshore drift was held approximately 5 to 10 m from the sonar transducers. The left bank offshore drift was approximately 65 m offshore of the transducers so as not to overlap with the nearshore drift. Drifts were approximately 8 minutes in duration, but were shortened as necessary to avoid snags or to limit catches during times of high fish passage.

Captured fish were identified to species and measured to the nearest 1 mm length. Salmon species were measured from mideye to fork of tail (METF); non-salmon species were measured from snout to fork of tail (FL). Fish species, length, and sex were recorded onto field data sheets. Each drift record included the date, sampling period, zone, drift start and end times, mesh size, length of net, and captain's initials.

The probability of a fish of a given species and length being captured in a net is dependent on mesh size. To adjust for the effect of net selectivity, a net selectivity model is used with coefficients generated for large and small Chinook salmon; summer and fall chum salmon; coho salmon; pink salmon *O. gorbuscha;* cisco *Coregonus sardinella* and *C. laurettae;* humpback whitefish *C. pidschian*; and broad whitefish *C. nasus*. In addition, coefficients have also been generated for a group of other species containing sheefish *Stenodus leucichthys;* burbot *Lota lota;* longnose sucker *Catostomus catostomus;* Dolly Varden *Salvelinus malma;* sockeye salmon *O. nerka;* and northern pike *Esox lucius* (Appendix A). Details of the apportionment model can be found in Bromaghin 2004.

Scale samples were collected from Chinook salmon and mounted on scale cards, and scale and card numbers were recorded on the test fishing data sheets. Data were transferred from data sheets into a database. Age, sex, and length (ASL) data were processed, analyzed, and reported by ADF&G staff based in Anchorage. Handling mortalities among the captured fish were distributed to the local community, with fish dispersal documented daily.

Genetic tissue samples from both Chinook and chum salmon were also collected. Age, sex, and length data were cross-referenced with each tissue sample. The ADF&G Gene Conservation Laboratory and the USFWS Conservation Genetics Laboratory independently processed and analyzed these samples.

Chinook salmon were classified as either 'large' (> 655 mm METF) or 'small' (≤ 655 mm METF), with small Chinook salmon serving as a proxy for one-ocean 'jacks'. Although there is some temporal overlap between the summer and fall runs of chum salmon, for the purposes of estimating passage, all chum salmon encountered through July 18 were designated as summer chum salmon, and those encountered after July 18 were designated as fall chum salmon.

ANALYTICAL METHODS

Daily estimates were produced from a multi-component process that involved the following:

a) Hydroacoustic estimates of all fish targets passing the site, without regard to species.

b) Species composition derived from test fishing results and applied to the undifferentiated hydroacoustic estimates.

c) Traditional CPUE estimates, used as a separate index by the managers and calculated on a subset of the test fishing data.

Sparse and Missing Data

Test fishing was not conducted during commercial fishery openings and occasionally, during periods of low salmon passage, catches were too sparse to accurately estimate species proportions and associated error bounds. When sufficient gillnet samples were not available for a given day and zone, the data were pooled with data from 1 or more adjacent days by assigning the same report unit *u*.

Traditional CPUE estimates were calculated on a daily basis irrespective of catch size. In contrast, sonar passage, species composition, and species passage estimates were first calculated on the basis of report units (encompassing 1 or more full days of sampling in a zone), and then apportioned to daily estimates. For any test fish variable *x* the report unit *u* encompasses day(s) *d*, test fish period(s) *p*, and zone(s) *z* such that

$$x_u = \sum_{d,p,z}^{u} x_{dpz} \quad . \tag{1}$$

The report unit was then also appended to the corresponding days and zones of sonar passage estimates. In effect, any unique combination of day and zone having sufficient test fish catch was also assigned a unique report unit *u*, while combinations not having sufficient catch were pooled by assigning the same report unit either across zones or days.

CPUE

Traditional CPUE measures were calculated for each day *d* and bank *b* using 2 gillnet suites *g* of specific size mesh *m*. Chinook salmon CPUE was calculated on the pooled catch *c* and effort *f* of the large mesh gillnets (7.5 in and 8.5 in); chum and coho salmon CPUE was calculated on the pooled catch and effort of the small mesh gillnets (5.25 in, 5.75 in, and 6.5 in).

The duration of the j^{th} test fish drift in minutes *t* was calculated as

$$t_j = (SIj - FOj) + \frac{(FOj - SOj)}{2} + \frac{(FIj - SIj)}{2}, \tag{2}$$

where *SO* is the time the net is initially set out, *FO* is the time the net is fully set out, *SI* is the time the net starts back in, and *FI* is the time the net is fully retrieved in.

The total fishing effort (in fathom-hours) for each day, bank, and gillnet suite was calculated as

$$f_{dbg} = \sum_g \frac{25 \cdot t_{dbg}}{60}, \tag{3}$$

because all nets were 25 fathoms (45.7 m) in length. CPUE estimates (in catch per fathom-hour) for each species *i* were made daily for the right and left banks as

$$CPUE_{dbi} = \frac{\sum_g c_{dbig}}{f_{dbg}}. \tag{4}$$

Species Composition

Test fishing drifts were made at stations in each of 3 zones (1, 2, and 3). Zone 1 consisted of the entire counting range on the right bank, zone 2 was from approximately 0–50 m on the left bank, and zone 3 was from approximately 50–300 m on the left bank. The results of the test fishing were used to generate species proportions for each zone, which were then applied to the corresponding sonar passage estimate in that zone.

To estimate species proportions, first the total effort *f* (in fathom-hours) of drift *j* with mesh size *m* during report unit *u* was calculated by multiplying the drift time *t* (calculated as in equation 3) for each mesh, drift, and reporting unit by 25 fathoms and dividing by 60 minutes per hour,

$$f_{umj} = \frac{25 \cdot t_{umj}}{60}. \tag{5}$$

Total effort for each mesh size fished was then summed over each report unit,

$$f_{um} = \sum_j f_{umj}, \tag{6}$$

and the catch of species *i* of length *l* in each report period was summed across all mesh sizes,

$$c_{uil} = \sum_m c_{uilm}, \tag{7}$$

for the catch of each species *i* of length *l*, the associated effort was adjusted by applying a length-based selectivity parameter *S* derived from the Pearson T net selectivity model

$$f'_{uil} = \sum_m \left(S_{ilm} \cdot f_{um}\right), \tag{8}$$

and the CPUE of the catch of each species *i* of length *l* was calculated as

$$CPUE'_{uil} = \frac{c_{uil}}{f'_{uil}}. \tag{9}$$

The proportion p of species i during report unit u was estimated as the ratio of the CPUE for species i to the CPUE of all species combined,

$$\hat{p}_{ui} = \frac{\sum_{l} CPUE'_{uil}}{\sum_{i,l} CPUE'_{uil}}, \tag{10}$$

and the variance was estimated from the squared differences between the proportion for each test fish period x for each day (d) within the report unit ($\hat{p}_{udxi}$), and the proportion for the report unit as a whole ($\hat{p}_{ui}$),

$$\hat{V}ar(\hat{p}_{ui}) = \frac{\sum \left(\hat{p}_{ui} - \hat{p}_{udxi} \right)^2}{n_u \cdot \left(n_u - 1 \right)}, \tag{11}$$

where n_u = number of test fish sampling periods within the report unit.

Sonar Passage Estimates

Total fish passage was estimated separately for each of the same 3 zones used in the test fish species apportionment. Zone 1 consisted of the entire counting range on the right bank, corresponding to strata 1 and 2 (approximately 0–150 m). Zone 2 consisted of the counting range corresponding to stratum 3 (approximately 0–50 m on the left bank). Zone 3 consisted of the counting range corresponding to stratum 4 and stratum 5 (approximately 50–150 m and 150–300 m on the left bank, respectively).

Within zone 2, passage was simultaneously estimated in sectors 1 and 2 (representing approximately the first 20 m of stratum 3) using both the DIDSON and the HTI sonar. Although the DIDSON data were primarily used to generate estimates in those 2 sectors, the HTI system data were also tallied because operating it in sectors 3, 4, and 5 also entailed operating in sectors 1 and 2. Since the ranges of the 2 systems did not always precisely overlap, a passage rate for the DIDSON (targets per meter per hour) was first calculated then expanded by the sector width and count time of the corresponding HTI sample to provide consistent width and count time for all sectors 1 through 5. This was done primarily as a matter of calculation convenience.

First, for sectors 1 and 2 of stratum 3, the sector widths w in meters were calculated for all samples q on day d, period p for both the DIDSON and HTI data. The DIDSON unit ensonifies over a single continuous range while the HTI subdivides this range into equal width sectors (k) 1 and 2 of stratum (s) 3. Sector widths for both systems are based on the start and end points of the range in meters referenced from the face of the transducer, such that,

$$w_{dpskq} = End_{dpskq} - Start_{dpskq}. \tag{12}$$

The mean width of sectors (k) 1 and 2 of the HTI samples were calculated

$$w_{HTI} = \frac{\sum_{s=3} \sum_{q} w_{dpksq}}{n}, \tag{13}$$

and the width of the DIDSON

$$w_{DID} = \frac{\sum_{q} w_{dpq}}{n}, \tag{14}$$

where n is the number of samples. The total hours h sampled with the HTI system,

$$h_{HTI} = \sum_{q} h_{dpkq}, \tag{15}$$

and the DIDSON,

$$h_{DID} = \sum_{q} h_{dpq}, \tag{16}$$

were summed, as were the total upstream counts y,

$$y_{HTI} = \sum_{q} y_{dpkq}, \tag{17}$$

$$y_{DID} = \sum_{q} y_{dpq}. \tag{18}$$

Passage rates (r) in fish per hour per meter were then calculated for both the DIDSON and the HTI systems,

$$r_{DID} = \frac{y_{DID}}{w_{DID} \cdot h_{DID}}, \tag{19}$$

$$r_{HTI} = \frac{y_{HTI}}{w_{HTI} \cdot h_{HTI}}. \tag{20}$$

Due to better detection capabilities at close range, and the aiming protocol described above, it was typical that the DIDSON passage rate would exceed the HTI passage rate in both sectors 1 and 2. In this case a passage estimate was generated for the time sampled by expanding the DIDSON using the HTI sector width and hours

$$y_{dpk} = r_{DID} \cdot w_{HTI} \cdot h_{HTI}. \tag{21}$$

However, in the event of a system failure or data loss using the DIDSON, the HTI estimate for those 2 sectors would be retained and used in subsequent calculations. In this case, the estimates for this time period would be considered conservative.

Total upstream fish passage y on day d during sonar period p in zone z and stratum s was then calculated by summing net upstream targets over all sectors k and samples q,

$$y_{dpzs} = \sum_q \sum_k y_{dpzsqk} \ , \tag{22}$$

and the duration, in hours h, of the time sampled as,

$$h_{dpzs} = \sum_q \sum_k h_{dpzsqk} \ . \tag{23}$$

The hourly passage rate r for day d, sonar period p, and zone z was computed as ratio of the sum of the estimated upstream passage in strata s to the duration (hours) of the sample,

$$r_{dpz} = \frac{\sum_s y_{dpzs}}{\sum_s h_{dpzs}} . \tag{24}$$

Total passage of fish in report unit was estimated as the product of the average hourly passage rate and the total hours encompassed by the report unit,

$$\hat{y}_u = \left(d_2 - d_1 + 1\right)_u \cdot 24 \cdot \left(\frac{\sum_{d,p,z \in u} r_{dpz}}{n_u} \right), \tag{25}$$

where d_1 is the first day, d_2 is the last day, and n_u is the number of sonar sampling periods in report unit u.

Sonar sampling periods, each 3 hours in duration, were spaced at regular (systematic) intervals of 8 hours. Treating the systematically sampled sonar counts as a simple random sample could yield an over-estimate of the variance of the total, since sonar counts are highly autocorrelated (Wolter 1985). To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations, recommended by Brannian[2] in 1986 and modified from Wolter (1985), was employed;

$$\hat{V}ar(\hat{y}_u) = \left[\left(d_2 - d_1 + 1\right)_u \cdot 24\right]^2 \cdot \left[1 - \frac{h_u}{\left(d_2 - d_1 + 1\right)_u \cdot 24}\right] \cdot \frac{\sum_{p=2}^{n_u} (\hat{r}_{up} - \hat{r}_{u,p-1})^2}{2n_u(n_u - 1)}, \tag{26}$$

where $\hat{r}_{up}$ is the estimated passage rate in reporting unit (u) for period (p), and

$$1 - \frac{h_u}{\left(d_2 - d_1 + 1\right)_u \cdot 24}, \tag{27}$$

is the finite population correction factor.

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[2] Brannian, L. 1986. Development of an approximate variance for sonar counts. 24 December Memorandum to William Arvey, AYK Regional Research Biologist, Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage.

Fish Passage by Species

The passage of species *i* was estimated for each report unit *u* as the product of the species proportion *p* (Equation 11) and sonar passage *y* (Equation 26),

$$\hat{y}_{ui} = \hat{y}_u \cdot \hat{p}_{ui} \,. \tag{28}$$

Except for the timing of sonar and gillnet sampling periods, sonar-derived estimates of total fish passage were independent of gillnet-derived estimates of species proportions. Therefore the variance of their product (daily species passage estimates y_{idz}) was estimated as the variance of the product of 2 independent random variables (Goodman 1960),

$$\hat{V}ar(\hat{y}_{ui}) = \hat{y}_u^2 \cdot \hat{V}ar(\hat{p}_{ui}) + \hat{p}_{ui}^2 \cdot \hat{V}ar(\hat{y}_u) - \hat{V}ar(\hat{y}_u) \cdot \hat{V}ar(\hat{p}_{ui}) \,. \tag{29}$$

Passage estimates were assumed independent between reporting units, so the variance of their sum was estimated by the sum of their variances

$$\hat{V}ar(\hat{y}_i) = \sum_u \hat{V}ar(\hat{y}_{ui}) \,. \tag{30}$$

Because most users of this data were interested in daily passage by species rather than passage for reporting units, the daily species passage by zone was estimated by calculating the proportion of the hourly passage rate for the day and zone to the hourly passage rate for the report unit,

$$\hat{p}_{dz} = \frac{r_{udz}}{r_u}, \tag{31}$$

and then applying the passage proportion *p* to the report unit estimate *y*,

$$\hat{y}_{dzi} = \hat{y}_{ui} \cdot \hat{p}_{dz} \,. \tag{32}$$

Total daily passage by species was estimated by summing over all zones,

$$\hat{y}_{di} = \sum_z \hat{y}_{dzi} \,. \tag{33}$$

At this stage, there were 2 potential ways of calculating total season passage – summing the estimates across days or reporting units. Each can produce slightly different totals due to small rounding errors. To prevent confusion, passage estimates were summed over all zones and days to obtain a seasonal estimate for species $y_{i,}$ (because this is how the estimates are reported)

$$\hat{y}_i = \sum_d \sum_z \hat{y}_{dzi} \tag{34}$$

Assuming normally distributed errors, 90% confidence intervals were calculated as,

$$\hat{y}_i \pm 1.645\sqrt{\hat{V}ar(\hat{y}_i)} \,. \tag{35}$$

SAS® program code (Toshihide Hamazaki, Commercial Fisheries Biometrician, ADF&G, Anchorage; personal communication) was used to calculate CPUE, passage estimates, and estimates of variance.

RESULTS

Test fishing and the right bank sonar were fully operational on June 1. The split-beam sonar and DIDSON were operational on the left bank on June 4. The project was fully operational from June 4 through September 7. Passage estimates were transmitted to fishery managers in Emmonak daily.

ENVIRONMENTAL AND HYDROLOGICAL CONDITIONS

Ice break-up on the Yukon River was sufficiently early to allow for camp set-up before June 1. The water level during the 2011 season was uncharacteristically high near Pilot Station and remained above the 2001–2010 mean throughout the season except for a period from June 20 to July 4 (Figure 4). Mean water temperature on the right bank ranged from 16.6°C to 11.4°C and 17.6°C to 12.8°C on the left bank from June 6 through September 7 (Figure 7).

TEST FISHING

Drift gillnetting resulted in the capture of 9,638 fish: 571 Chinook salmon, 3,951 summer chum salmon, 2,615 fall chum salmon, 850 coho salmon, and 1,651 fish of other species. Of the captured fish, 2,982 were retained as mortalities and delivered to local users within the nearby community of Pilot Station (Table 6).

Daily CPUE data is reported in Appendices B1 and B2. The relationship between daily passage estimates and test fishery CPUE for Chinook salmon, summer and fall chum salmon, and coho salmon were all significant (Figure 8). The correlation coefficient for Chinook salmon was $r = 0.880$ ($P < 0.001$), summer chum salmon was $r = 0.889$ ($P < 0.001$), fall chum salmon was $r = 0.954$ ($P < 0.001$), and coho salmon was $r = 0.805$ ($P < 0.001$).

HYDROACOUSTIC ESTIMATES

An estimated 3,691,528 fish passed through the sonar sampling areas between June 1 and September 7: 1,145,720 (31%) along the right bank, 1,757,809 (48%) along the left bank nearshore, and 787,999 (21%) along the left bank offshore (Table 7). Daily total passage estimates by zone, with their associated errors, are provided in Appendix C.

On the left bank, approximately 90% of the fish passage occurred within 90 m from the transducer in the summer season (through July 18). During the fall season (post July 18), distribution dispersed slightly with 90% of the passage occurring within 110 m. On the right bank, approximately 90% of total fish passage occurred within 70 m in both summer and fall seasons (Figure 9).

SPECIES ESTIMATES

Fish passage estimates by species were generated and reported daily to fishery managers Appendix D. Cumulative passage estimates[3] for summer chum salmon were composed of 1,977,808 ± 81,199 summer chum salmon and 764,194 ± 49,791 fall chum salmon. Although Chinook salmon were first captured on June 1 in the project's test fishery, passage estimates for Chinook salmon were not generated until June 4, when the project was fully operational. Chinook salmon were composed of 100,217 ± 16,952 large Chinook salmon (>655 mm METF)

[3] Cumulative estimates for all fish species include 90% confidence intervals.

and 23,152 ± 5,491 small Chinook salmon (≤655 mm METF). Coho salmon passage estimates were 124,931 ± 21,171, and the estimate of pink salmon was 6,526 ± 2,959. Other species, totaling 694,700 ± 58,593 fish, included whitefish, cisco, sheefish, burbot, longnose sucker, Dolly Varden, sockeye salmon, and northern pike. Both Chinook and coho salmon were below average, while summer and fall chum salmon were above average compared to 2001–2010 historical passage estimates (Appendix E).

Of the total passage, 15,813 Chinook salmon, 207,027 summer chum salmon, 79,985 fall chum salmon, and 10,772 coho salmon were additionally counted by the DIDSON within the 0 to 20 m region of the left bank nearshore (sectors 1 and 2 of stratum 3). The daily estimates of fish passing through this region of the left bank and the associated proportion also referred to as the DIDSON contribution (Appendices F1 and F2), were monitored daily to evaluate the performance of the split-beam.

The first major pulse of Chinook and summer chum salmon began on approximately June 16 (Figure 10). The midpoints of the runs occurred on June 23 for Chinook, and June 25 for summer chum salmon. Comparison of the mean run timing for the years 2001 through 2010 indicate the overall timing of summer chum salmon was 7 days early and Chinook salmon run timing was 4 days early (Figure 11; Appendix G).

During the fall season, the first pulse of fall chum salmon occurred July 19 with the midpoint of the run passing Pilot Station on August 10. Coho salmon were first detected July 21, with the largest pulse starting on August 23 (Figure 12). As in most years, the project ends before the coho salmon run is complete, so estimates are considered conservative. Fall chum salmon timing was 3 days early and coho salmon run timing was 3 days late (Figure 13; Appendix G).

MISSING DATA

Due to heavy wind, debris, or wave action, there were 8 days during the season that it was not feasible to collect 3 full periods of sonar data on both banks. During the summer season, 5 commercial fishing periods occurred in District 2 (Figure 1) during at least 1 of the test fishing periods, and during the fall season, 6 commercial periods occurred during a test fishing period. Additionally, there were 7 days during the season when insufficient numbers of fish were captured. In order to estimate variance accurately, days with missing test fishing periods were pooled with adjacent days that had 2 complete test fishing periods, and zones with insufficient catches were pooled with zones with sufficient catches on adjacent days (Table 8).

DISCUSSION

During the 2011 season, the ice on the Yukon River broke up on May 17 at Pilot Station, which is average compared to 2001–2010 timing (Figure 14). Throughout the field season, water levels remained above average except for a period between June 20 and July 4, when the water level receded below the historic average (Figure 4). Heavy drift and silty conditions during the first week of the field season were problematic for sonar deployment, target detection, and testfishing on both banks. Environmental conditions prevented collection of sonar data on the left bank through June 4.

The Lower Yukon 8.5 inch test fishery assessment project (LYTF) operated by ADF&G and the Yukon River Drainage Fisheries Association (YRDFA) in Emmonak (Figure 1) also experienced difficulties with high water and debris through approximately June 27, which made run assessment difficult. Due to the uncertainty concerning Chinook salmon run strength and the need to fulfill the Canadian border passage obligation, meet Alaska escapement needs, and provide for subsistence uses, no commercial periods targeting Chinook salmon were allowed in 2011 in the Yukon River mainstem. In an effort to reduce incidental harvest of Chinook salmon during a poor run, management actions regarding the summer chum commercial salmon fishery were delayed until near the midpoint in the Chinook salmon run at the LYTF. At that time, a harvestable surplus of summer chum had been identified because a total run size of approximately 2 million summer chum salmon was projected based on Pilot Station sonar[4]. Fall season run assessment also indicated that there was a surplus of fall chum salmon available for commercial harvest and commercial fishing during the 2011 season. The fall chum salmon harvest was the largest since 1995, and the coho salmon harvest was the largest since 1991[5].

A silt band, which was present from the beginning of the summer season until June 21, limited target detection from approximately 10 to 15 m offshore. Targets beyond the band were identifiable throughout the remaining range (Figure 15). It was ambiguous if fish passage was present in the silt band, or if fish generally avoided the band. Because of uncertainty of the accuracy of the sonar counts, side-scan sonar was deployed from a skiff offshore on the left bank from June 8 through July 7. Side-scan sampling periods corresponded with the period 2 shore-based sonar schedule, sampling all 3 strata of the left bank. Side-scan sonar counts compared to passage rates with the split-beam and DIDSON sonars revealed lower passage rates within the first 20 m (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication), which was the area of concern at the time. Inseason passage estimates relayed to managers during this period were considered conservative[6]. Distribution of fish from 50 to 100 m were similar between the side-scan and the shore based sonars, and use of the side-scan sonar should continue to be considered in the future to be used as a check in situations where there is limited detection beyond the nearshore range of the shore-based sonars.

The right bank bottom profile was similar to prior years with little or no change throughout the season. Left bank profiles remained linear, and there were no problems in finding suitable transducer locations. Bathymetric surveys of the river near the sonar site this season indicated little change from previous surveys conducted in 2009. There were no indications of a reformation of the mid-channel sandbar, which was found to have regressed (Lozori and McIntosh 2013) and had been speculated to affect fish distribution in the past (Rich 2001). More of a concern in recent years has been the left bank sand bar downstream of the ensonified area of the left bank. Considerable shallowing of the substrate on the left bank has been noted, and significant profile changes have been observed. During the 2011 season, the left bank sandbar did not seem to affect fish distribution or the test fishery. Although above-average water levels (Figure 4) may have limited the sandbar's effect on fish distribution and the project's test fishery, the sand bar should continue to be monitored in the future. Investigations in regard to alternative

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4 Hayes, S. 2011. 2011 Preliminary Yukon River summer season summary, Alaska Department of Fish and Game. Division of Commercial Fisheries, News Release Juneau, AK [issued 2011 September 30; cited February 2013]. Available from http//www.adfg.alaska.gov/static/home/news/pdfs/newsreleases/cf/90349313.pdf (Accessed February 2013)

5 Estensen, J. 2011. 2011 Yukon River fall summary. Alaska Department of Fish and Game. Division of Commercial Fisheries, News Release Juneau AK [issued 2011 November 7; cited February 2013]. Available from http//www.adfg.alaska.gov/static/home/news/pdfs/newsreleases/cf/96763790.pdf (Accessed February 2013)

6 Hayes, S. 2011. 2011 Yukon River summer salmon fishery News Release #49, Alaska Department of Fish and Game. Division of Commercial Fisheries, News Release Juneau, AK [issued 2011 July 18; cited February 2013]. Available from http//www.adfg.alaska.gov/static/home/news/pdfs/newsreleases/cf/45433436.pdf (Accessed February 2013)

test fish and sonar protocols should be considered in the event the sand bar continues to shallow and cause detection as well as apportionment issues in the future.

The DIDSON contribution is defined as the additional fish count supplemented over and beyond the split-beam estimate within the first 20 m of the nearshore stratum. The DIDSON contribution this season was 12.8% Chinook, 10.4% for both summer and fall chum salmon, and 8.6% coho salmon. The DIDSON contribution showed an increase over the 2009 and 2010 contribution for all of these species. Comparisons of DIDSON contributions since 2005 highlight that although the DIDSON complements the sonar sampling plan on the left bank, the nature of the left bank substrate, water level, and fish distribution all are factors in determining the DIDSON's relative contribution to the overall passage estimate in any given season (Figure 16).

In 2011, all project goals were met with passage estimates given to fisheries managers daily during the season. Information generated at the Pilot Station sonar project was also disseminated weekly through multi-agency international teleconferences and data-sharing with stakeholders in areas from the lower Yukon River all the way to the spawning grounds in Canada.

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TABLES AND FIGURES

Table 1.–Initial split-beam sonar settings at the Pilot Station sonar project on the Yukon River, 2011.

			Bank	
Component	Setting	Stratum	Left	Right
Transducer	Beam size (h x w)		2.8º x 10.0º	6.0º x 10.0º
Echosounder	Transmit power (dB)		27.0	27.0
	Receiver gain (dB)	S1		-12.0
		S2		-12.0
		S3	-12.0	
		S4	-12.0	
		S5	0.0	
	Source Level (dB)		223.4	216.8
	Through-system gain (dB)		-161.5	-162.0
	Pulse width (ms)		0.5	0.5
	Blanking range (m)		2.0	2.0
	Ping rate (pps)	S1		5.0
		S2		3.0
		S3	5.0	
		S4	3.0	
		S5	1.3	
	Range (m)	S1		50
		S2		150
		S3	50	
		S4	150	
		S5	300	

Table 2.–Technical specifications for the dual-frequency identification sonar at the Pilot Station sonar project on the Yukon River, 2011.

Identification Mode		
	Operating Frequency	1.2 MHz
	Beam width (two-way)	0.5° H by 14° V
	Number of beams	48
Range Settings		
	Start range	0.83 m
	Window length	20.01 m
Range bin size		39 mm
Pulse length		46 µs
Frame rate		8 frames/s
Field of view (horizontal)		29°

Table 3.–Daily sampling schedule for sonar and test fish.

Time	Sonar Right Bank	Sonar Left Bank	Test fishing
	Period 1		
0530	S1	S3	
0600	S2	S4	
0630	S1	S5	
0700	S2	S3	
0730	S1	S4	
0800	S2	S5	
0830			
0900			Period 1
0930			
1000			
1030			
1100			
1130			
1200			
1230			
1300	Period 2		
1330	S1	S3	
1400	S2	S4	
1430	S1	S5	
1500	S2	S3	
1530	S1	S4	
1600	S2	S5	
1630			
1700			Period 2
1730			
1800			
1830			
1900			
1930			
2000			
2030			
2100	Period 3		
2130	S1	S3	
2200	S2	S4	
2230	S1	S5	
2300	S2	S3	
2330	S1	S4	
0000	S2	S5	

Note: S1 = stratum 1, S2 = stratum 2, etc. at the Pilot Station sonar project on the Yukon River, 2011.

Table 4.–Specifications for drift gillnets used for test fishing by season, at the Pilot Station sonar project on the Yukon River, 2011.

	Stretch mesh size		Mesh Diameter	Meshes Deep	Depth
Season	(in)	(mm)	(mm)	(MD)	(m)
Summer	2.75	70	44	131	8.0
(6/01–7/18)	4.00	102	65	90	8.0
	5.25	133	85	69	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0
	8.50	216	137	43	8.1
Fall	2.75	70	44	131	8.0
(7/18–9/07)	4.00	102	65	90	8.0
	5.00	127	81	72	8.0
	5.75	146	93	63	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0

Table 5.–Schedule for drift gillnets used for test fishing by season, at the Pilot Station sonar project on the Yukon River, 2011.

		Odd Day Mesh Size (in)		Even Day Mesh Size (in)	
Season	Period	Drift 1	Drift 2	Drift 1	Drift 2
Summer	1	2.75	5.25	8.50	4.00
(6/01–7/18)		7.50	6.50	7.50	6.50
	2	7.50	6.50	7.50	6.50
		8.50	4.00	2.75	5.25
Fall	1	4.00	5.75	2.75	7.50
(7/19–9/07)		5.00	6.50	5.00	6.50
	2	5.00	6.50	5.00	6.50
		2.75	7.50	4.00	5.75

Table 6.–Number of fish caught and retained in the Pilot Station sonar test fishery on the Yukon River, 2011.

Total Catch	Chinook	Summer Chum	Fall Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
June	422	2,201	0	0	0	0	20	59	6	137	5	2,850
July	146	1,750	609	19	11	20	177	165	0	22	12	2,931
August	3	0	1,796	8	703	11	368	381	11	8	17	3,306
September	0	0	210	3	136	3	78	106	10	2	3	551
Total	571	3,951	2,615	30	850	34	643	711	27	169	37	9,638

Fish Retained	Chinook	Summer Chum	Fall Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others	Total
June	165	1,010	0	0	0	0	13	23	6	67	1	1,285
July	33	530	78	6	1	0	142	52	0	9	0	851
August	0	0	371	0	74	0	223	50	4	2	0	724
September	0	0	60	2	21	0	38	0	1	0	0	122
Total	198	1,540	509	8	96	0	416	125	11	78	1	2,982

Proportion Retained	Chinook	Summer Chum	Fall Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others	Total
June	0.391	0.459	0.000	0.000	0.000	0.000	0.000	0.390	1.000	0.489	0.200	0.451
July	0.226	0.303	0.128	0.316	0.091	0.000	0.802	0.315	0.000	0.409	0.000	0.290
August	0.000	0.000	0.207	0.000	0.105	0.000	0.606	0.131	0.364	0.250	0.000	0.219
September	0.000	0.000	0.286	0.667	0.154	0.000	0.487	0.000	0.100	0.000	0.000	0.221
Total	0.347	0.390	0.195	0.267	0.113	0.000	0.647	0.176	0.407	0.462	0.027	0.309

[a] Includes longnose sucker, northern pike, and Dolly Varden.

Table 7.–Cumulative fish passage estimates by zone and species at Pilot Station sonar, with standard error (SE) and 90% confidence intervals (CI), 2011.

		Left Bank				90% CI	
Species	Right Bank	Nearshore	Offshore	Total Passage	SE	Lower	Upper
Large Chinook [a]	10,735	63,683	25,799	100,217	10,305	83,266	117,168
Small Chinook	4,265	14,933	3,954	23,152	3,338	17,660	28,644
Summer chum	660,044	970,125	347,639	1,977,808	49,361	1,896,608	2,059,008
Fall chum	122,354	340,095	301,745	764,194	30,268	714,404	813,984
Coho	28,534	38,271	58,126	124,931	12,870	103,759	146,103
Pink	2,759	3,767	0	6,526	1,799	3,566	9,486
Other	317,029	326,935	50,736	694,700	35,619	636,106	753,294
Total	1,145,720	1,757,809	787,999	3,691,528			

[a] Large Chinook are >655 mm mideye to tail fork, small Chinook ≤655 mm mideye to tail fork.

Table 8.–Reporting units of zones pooled for the 2011 season at the Pilot Station sonar site on the Yukon River.

		Left Bank		
Date	Right Bank (Zone 1)	Nearshore (Zone 2)	Offshore (Zone 3)	Reason for pooling [a]
6/01				
6/02				
6/03	1	2		MD
6/04				
6/05			9	MD
6/06	13			MD
6/07				
6/08	19	20	21	MD
6/09				
6/10	22			IC
6/14				
6/15	37	38	39	IC
6/17				
6/18	43	44	45	IC
6/20				
6/21	49	50	51	IC
6/27				
6/28	70	71	72	IC
7/01				
7/02	79	80	81	IC
7/07				
7/08	94	95	96	CO
7/10				
7/11	100	101	102	CO
7/12				
7/13	103	104	105	CO
7/14				
7/15	106	107	108	CO
7/16				
7/17	109	110	111	CO
7/23				
7/24				
7/25	127	128	129	IC

-continued-

Table 8.–Page 2 of 2.

Date	Right Bank (Zone 1)	Left Bank Nearshore (Zone 2)	Left Bank Offshore (Zone 3)	Reason for pooling [a]
8/01 8/02	148	149	150	CO
8/06 8/07	160	161	162	CO
8/09 8/10	166	167	168	CO
8/14 8/15	178	179	180	CO
8/16 8/17	181	182	183	CO
8/23 8/24	199	200	201	CO

[a] CO denotes that a commercial opening prevented test fishing; therefore, pooling across days enables the variance estimation of species proportions. IC denotes that zones were pooled when there was insufficient catch in the test fishery for variance estimation. MD denotes that zones were pooled when there was missing sonar data.

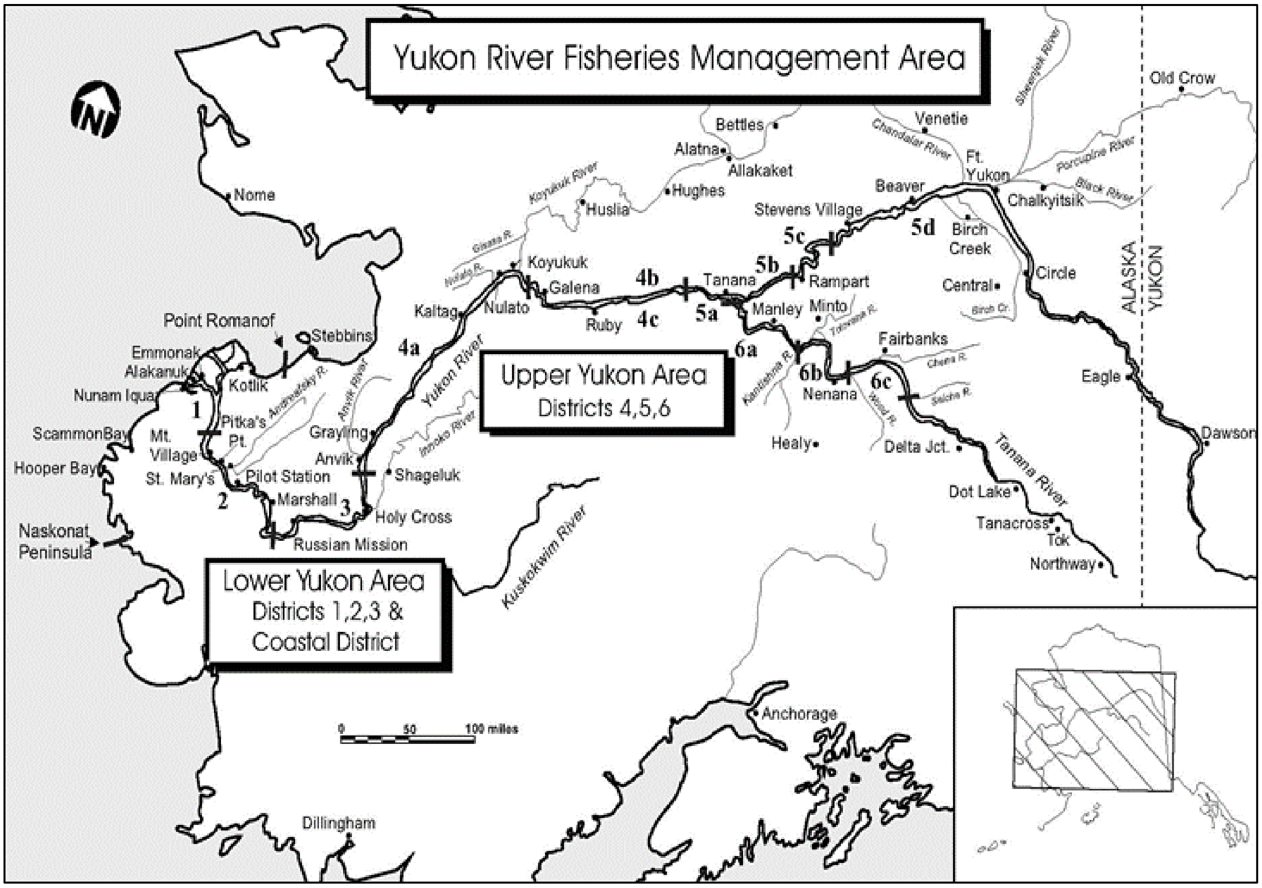


Figure 1.–Fishing districts and communities of the Yukon River watershed.

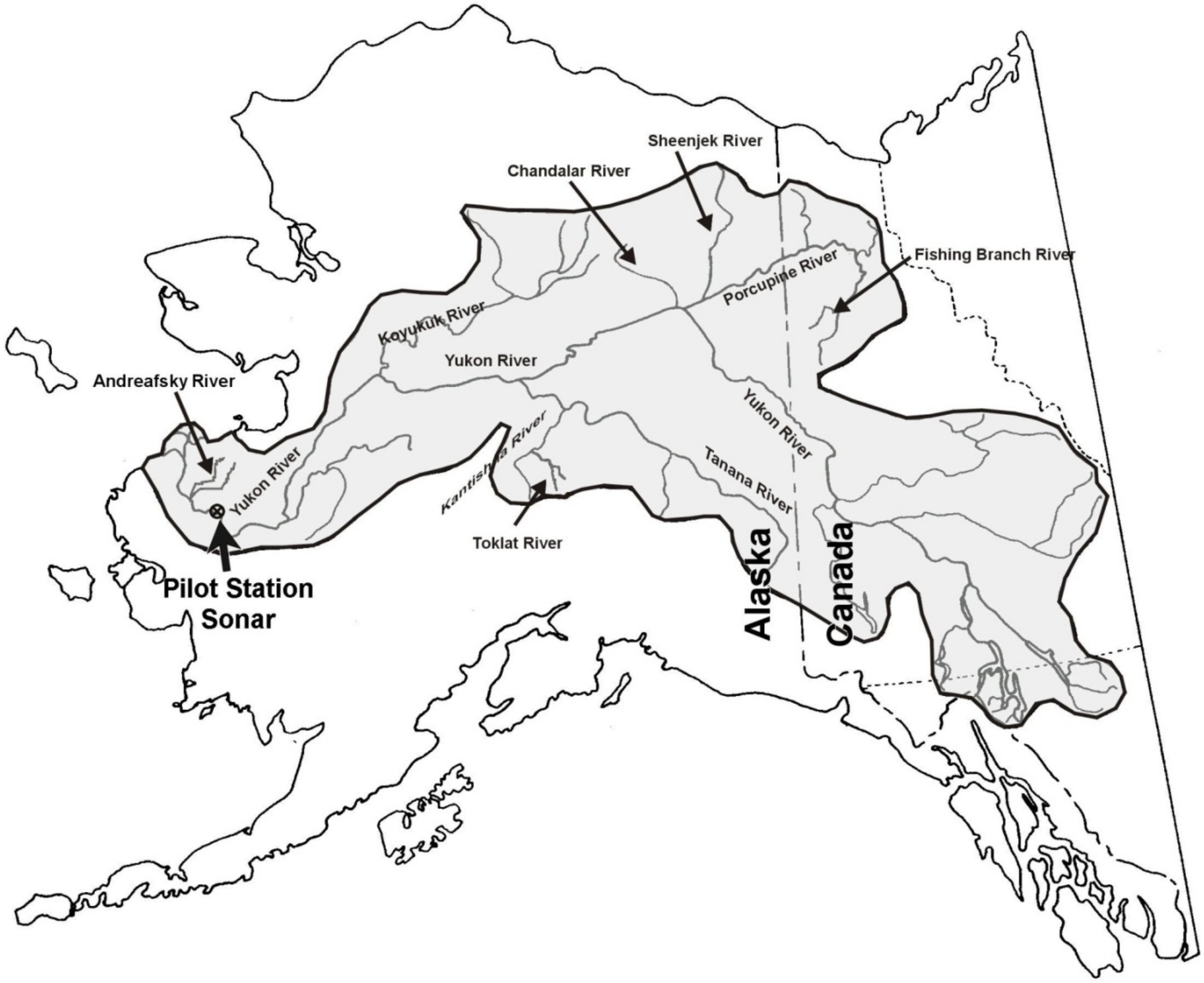


Figure 2.–Extent of Yukon River drainage.

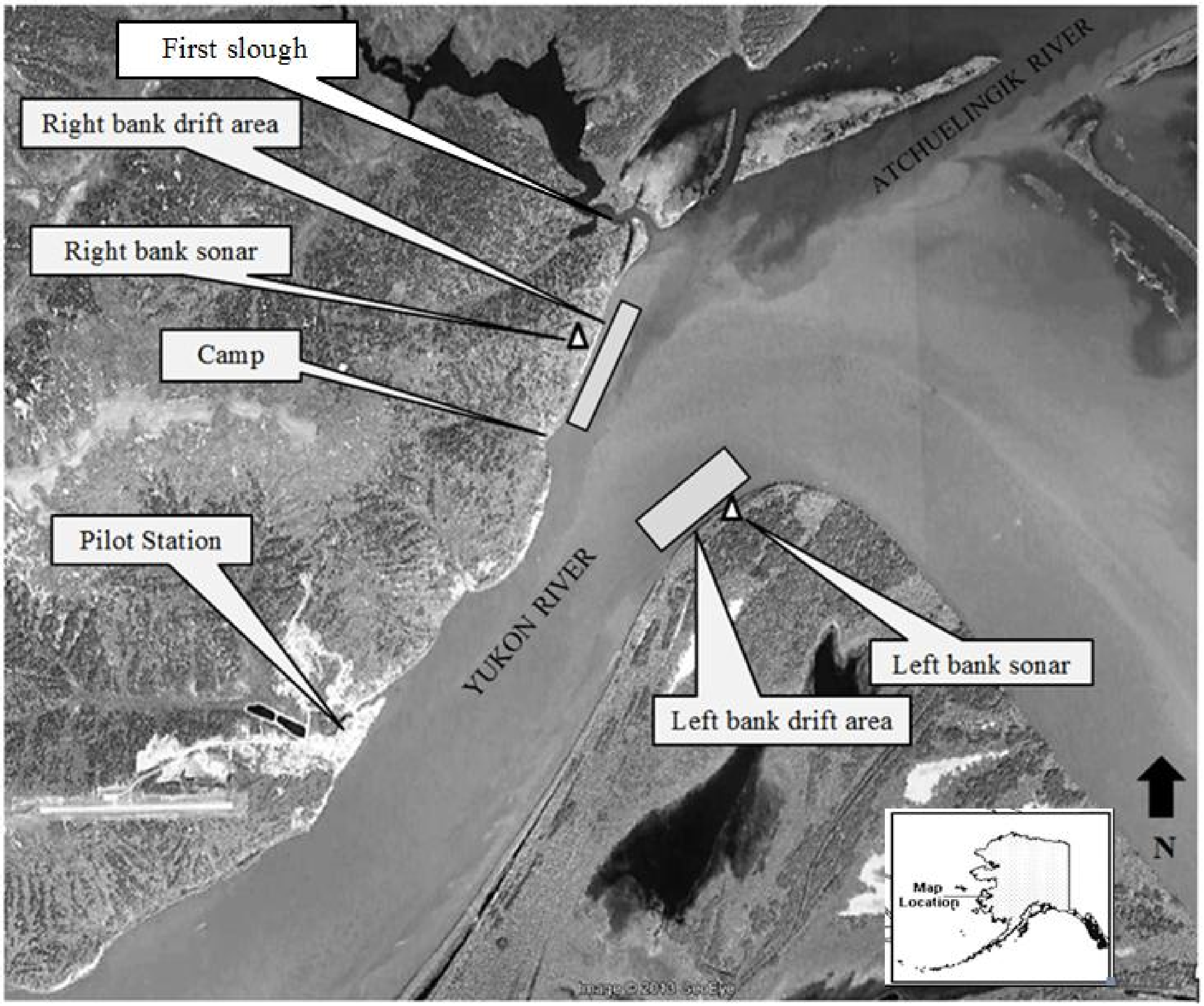


Figure 3.–Location of the Pilot Station sonar project on the Yukon River, showing general transducer and drift gillnet fishing locations.

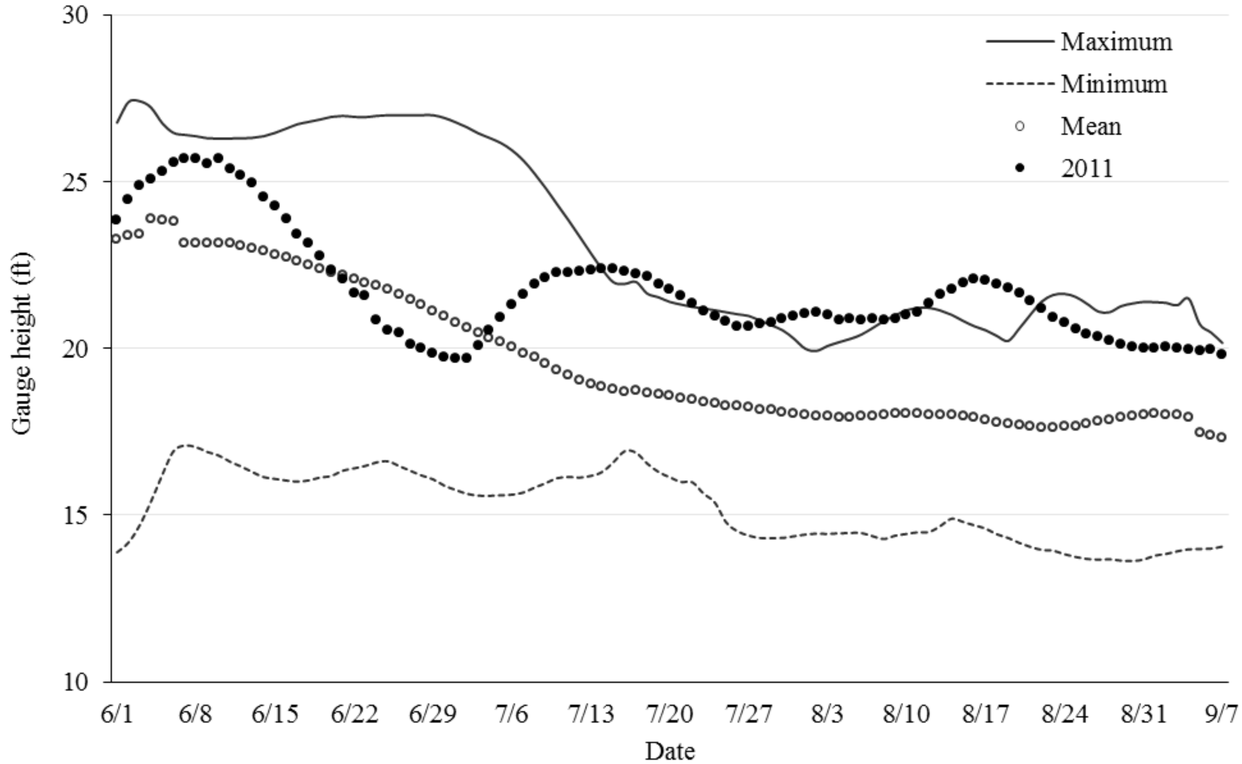


Figure 4.–Yukon River daily water level during the 2011 season at Pilot Station water gage compared to minimum, maximum, and mean gage height 2001 to 2010.

Source: United States Geological Service.

Note: Missing values were estimated using linear interpolation.

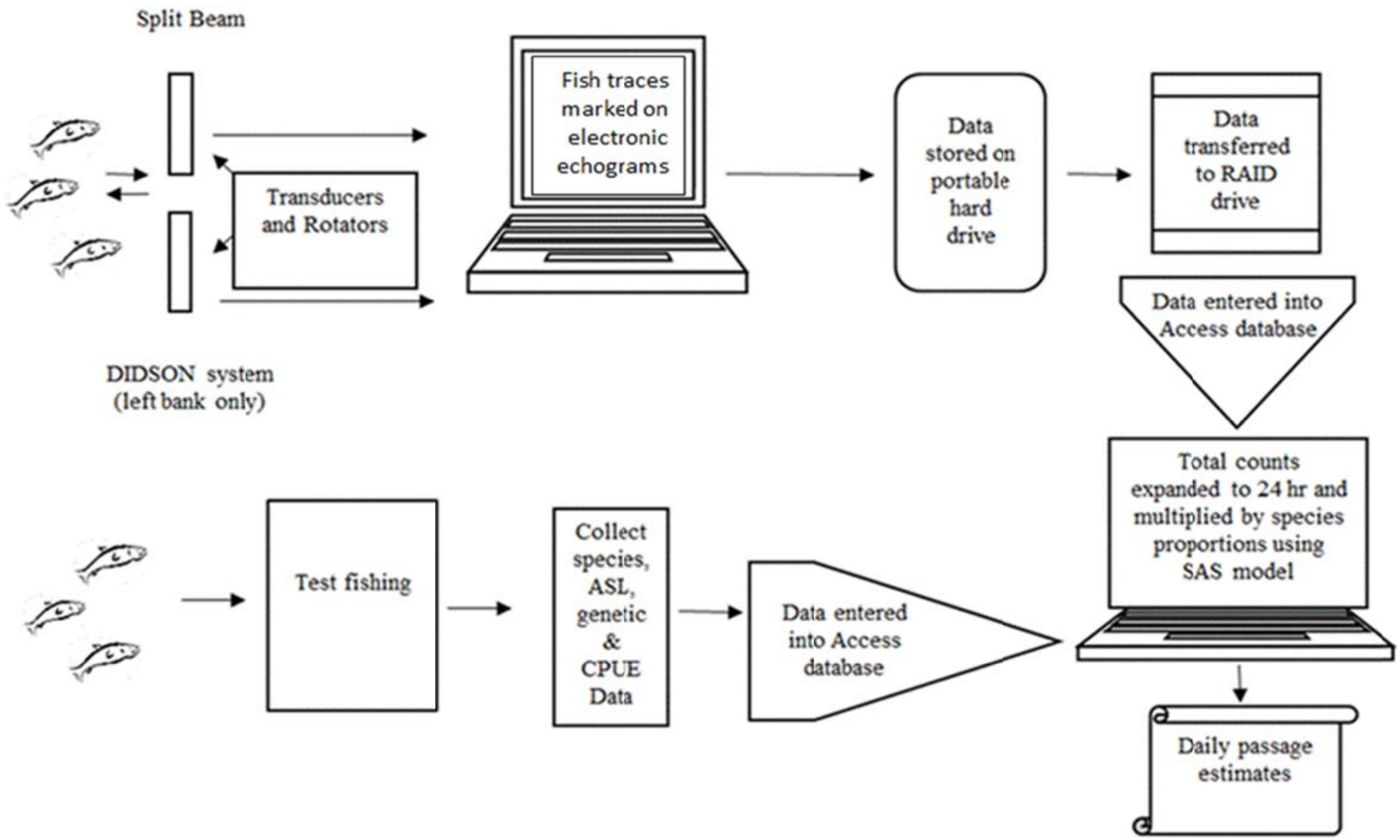


Figure 5.–Flow diagram of data collection and processing at the Pilot Station sonar project on the Yukon River, 2011.

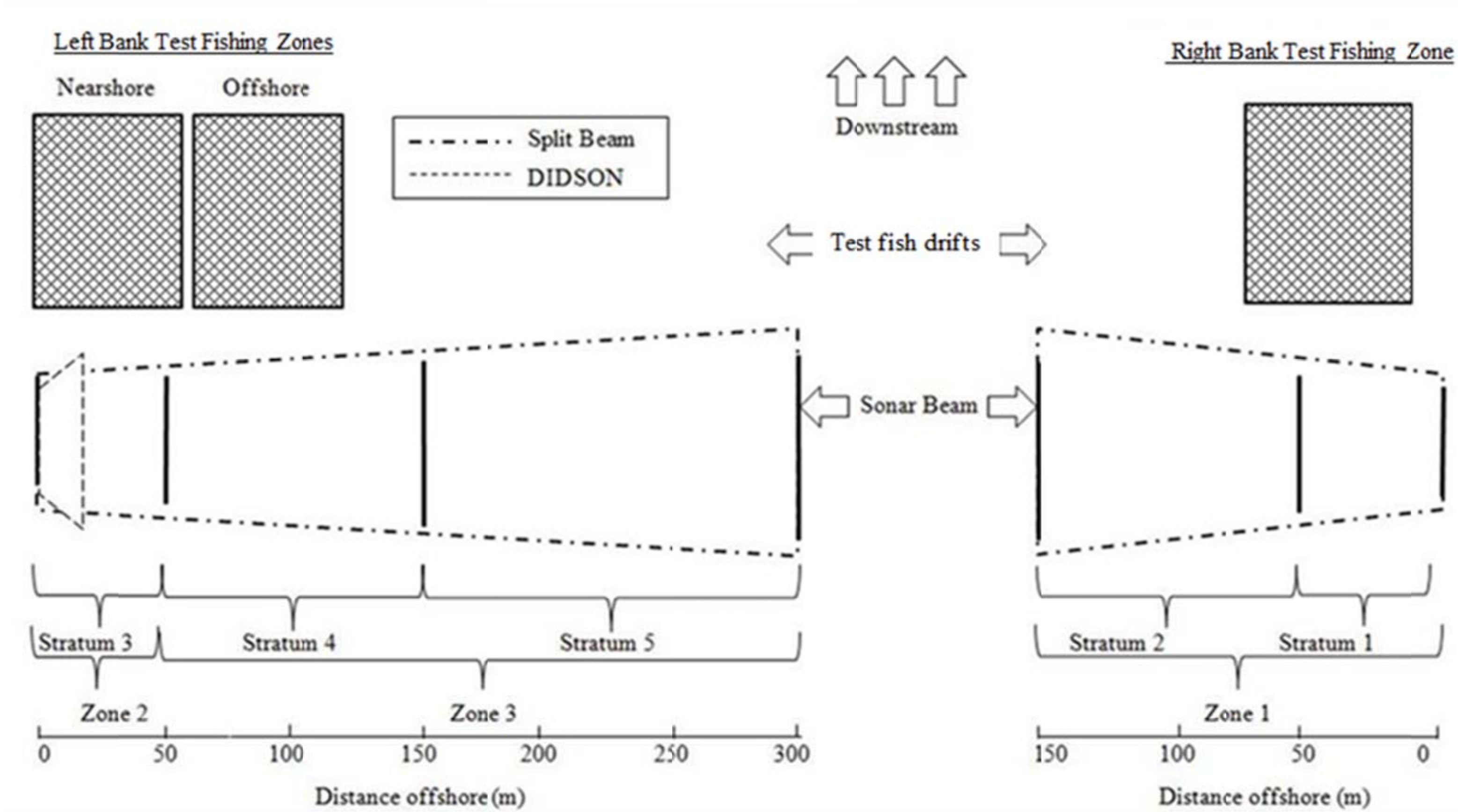


Figure 6.–Illustration of relationships between strata, sectors, zones, test fish drifts, and approximate sonar ranges (not to scale) at the Pilot Station sonar project on the Yukon River, 2011.

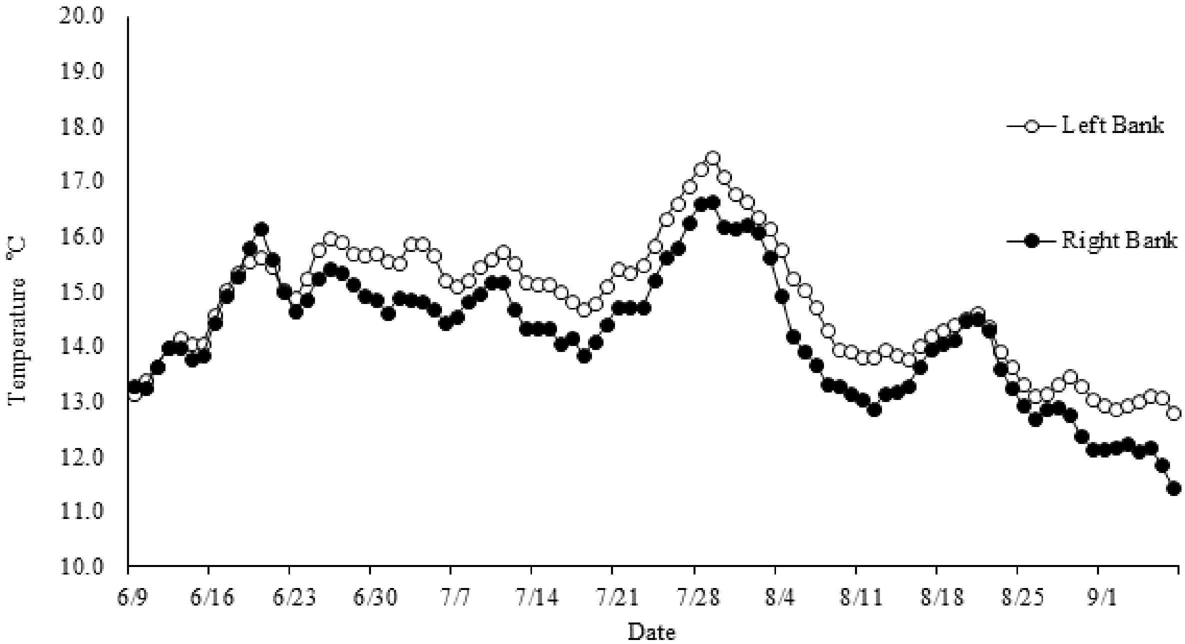


Figure 7.–Mean daily water temperatures recorded at the Pilot Station sonar project on the Yukon River with electronic data loggers by bank, 2011.

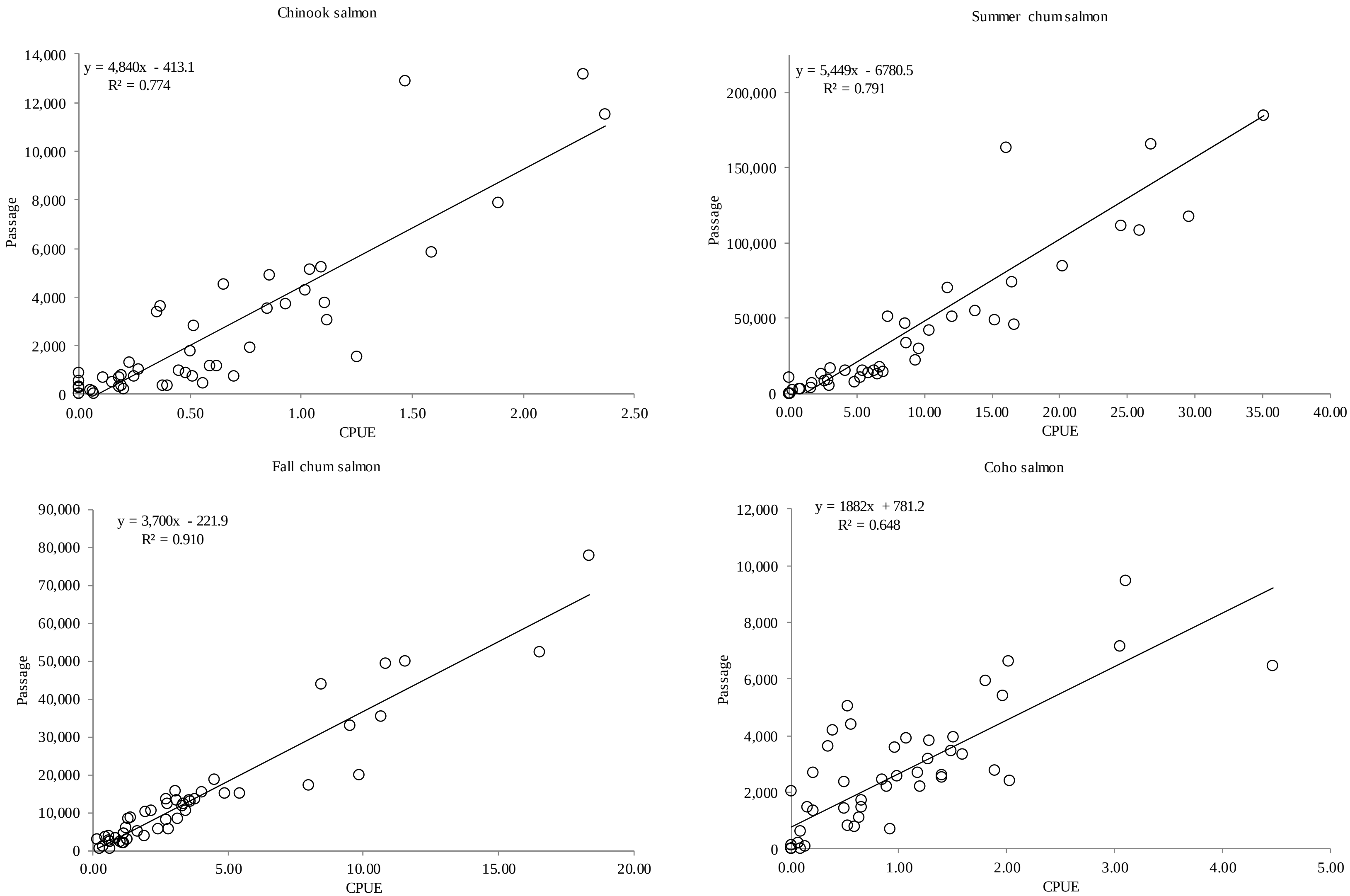
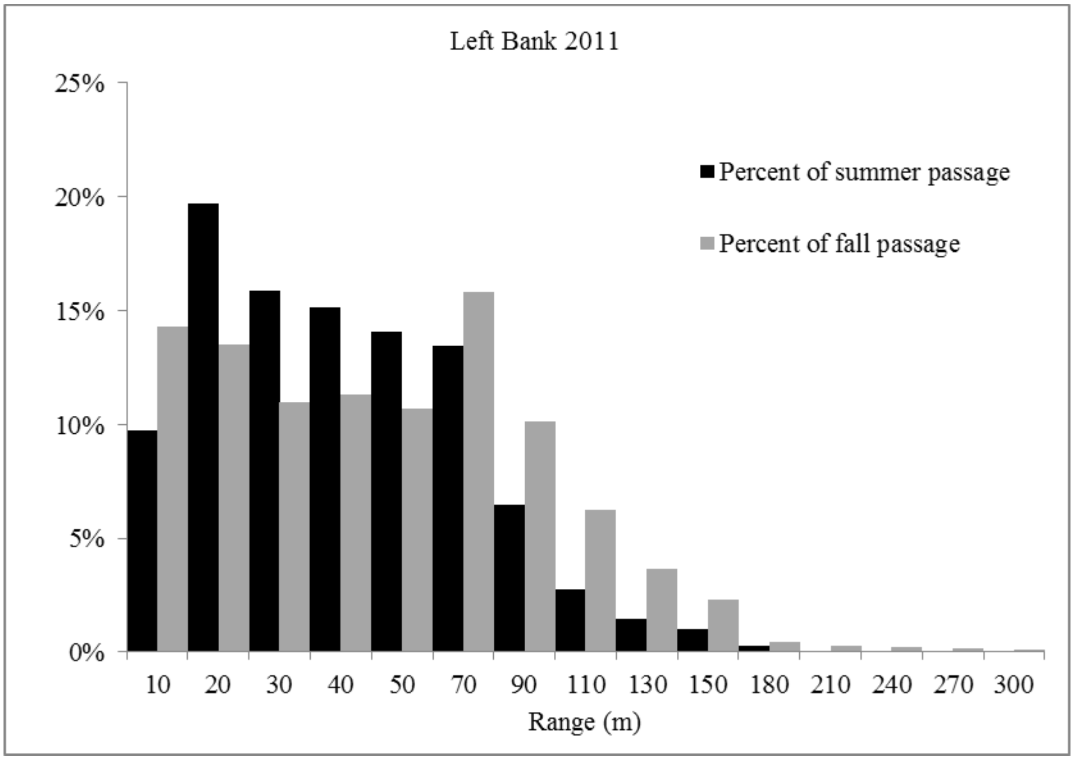


Figure 8.–Scatter plots of daily fish passage versus catch per unit of effort (CPUE) for Chinook, summer chum, fall chum, and coho salmon, at the Pilot Station sonar project on the Yukon River, 2011.



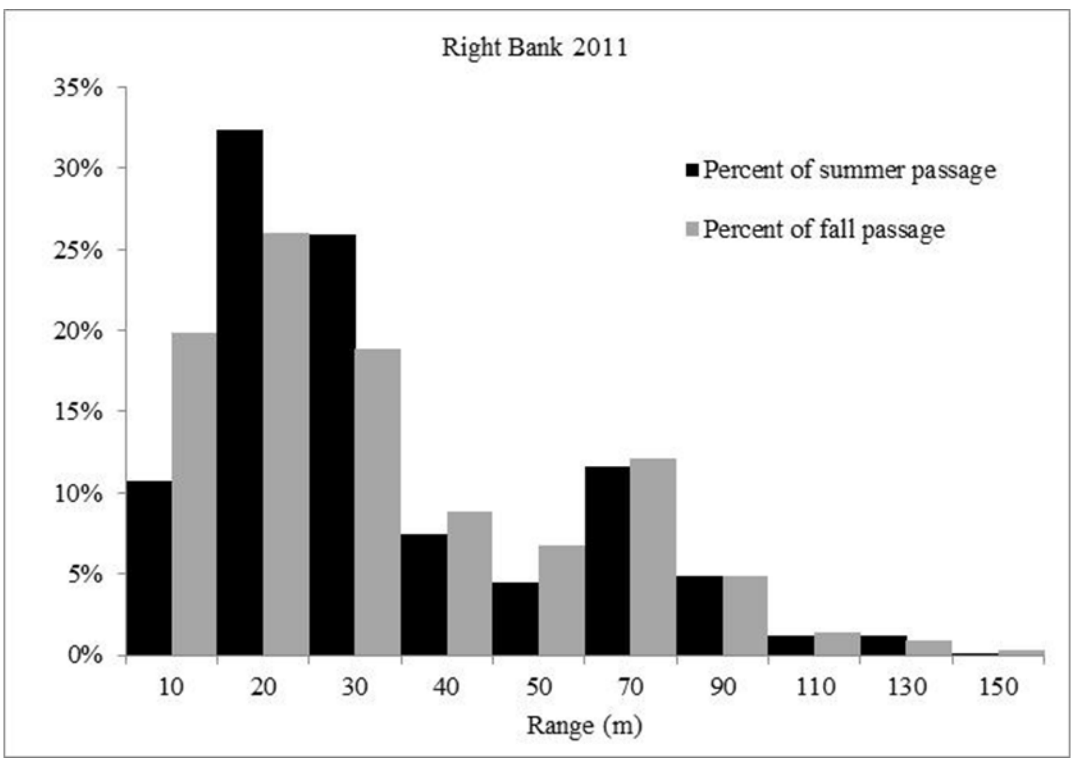


Figure 9.–Horizontal fish distribution (distance from transducer) by bank and season, at the Pilot Station sonar project on the Yukon River, 2011.

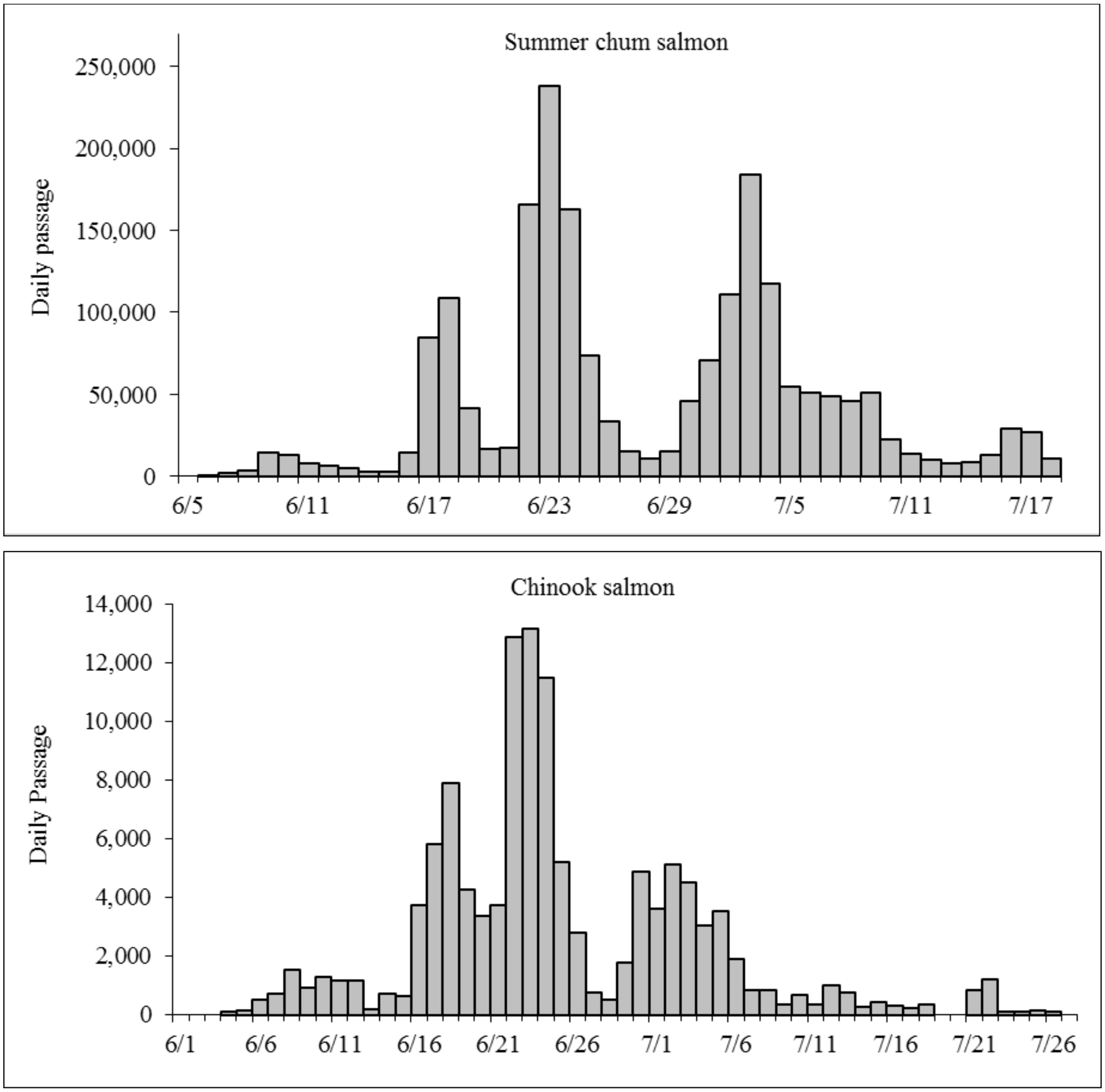


Figure 10.–Summer chum and Chinook salmon daily passage estimates, at the Pilot Station sonar project on the Yukon River, 2011.

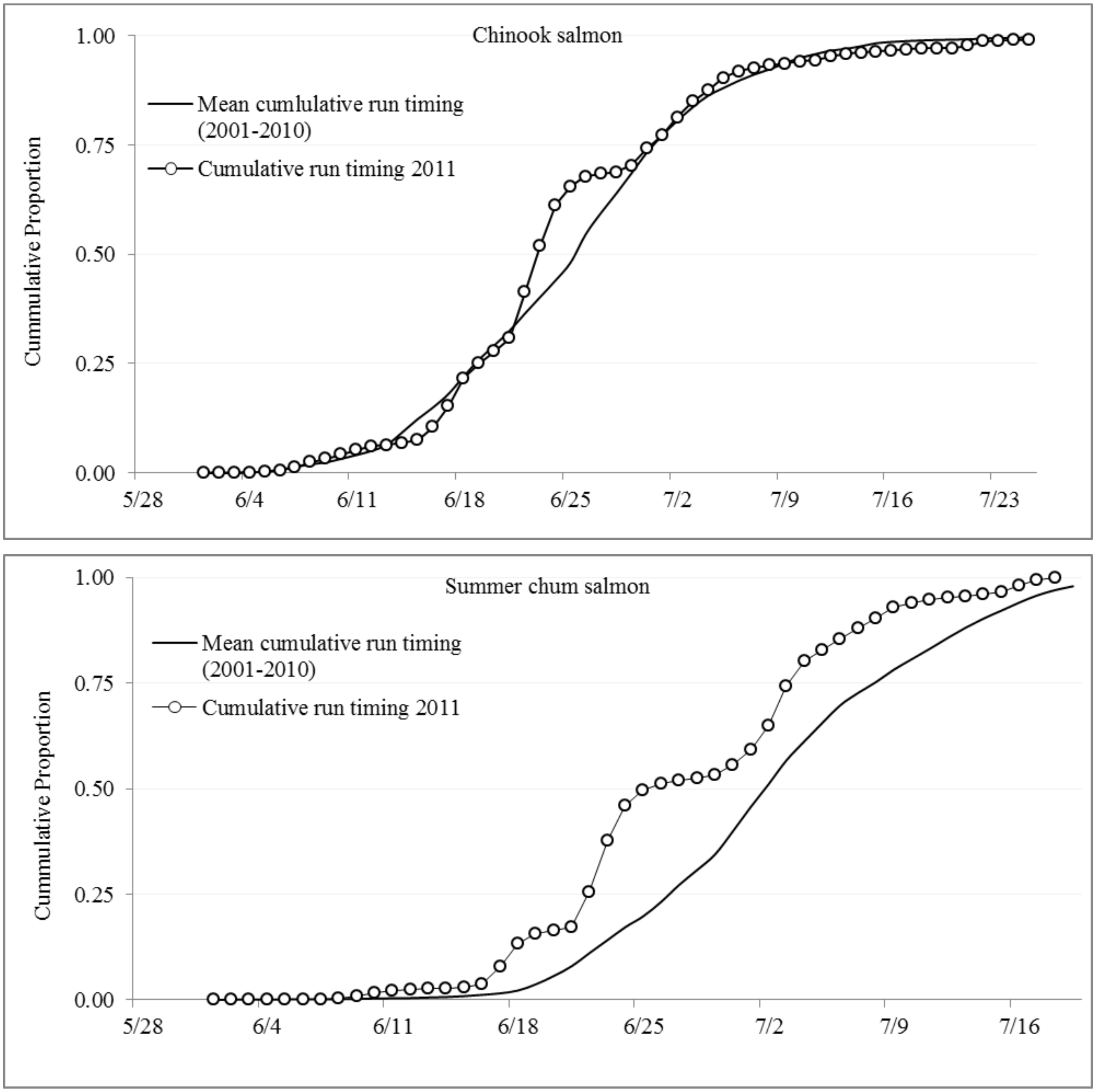


Figure 11.–2011 Chinook and summer chum salmon daily cumulative passage timing compared to the 2001–2010 mean passage timing at the Pilot Station sonar project, on the Yukon River.

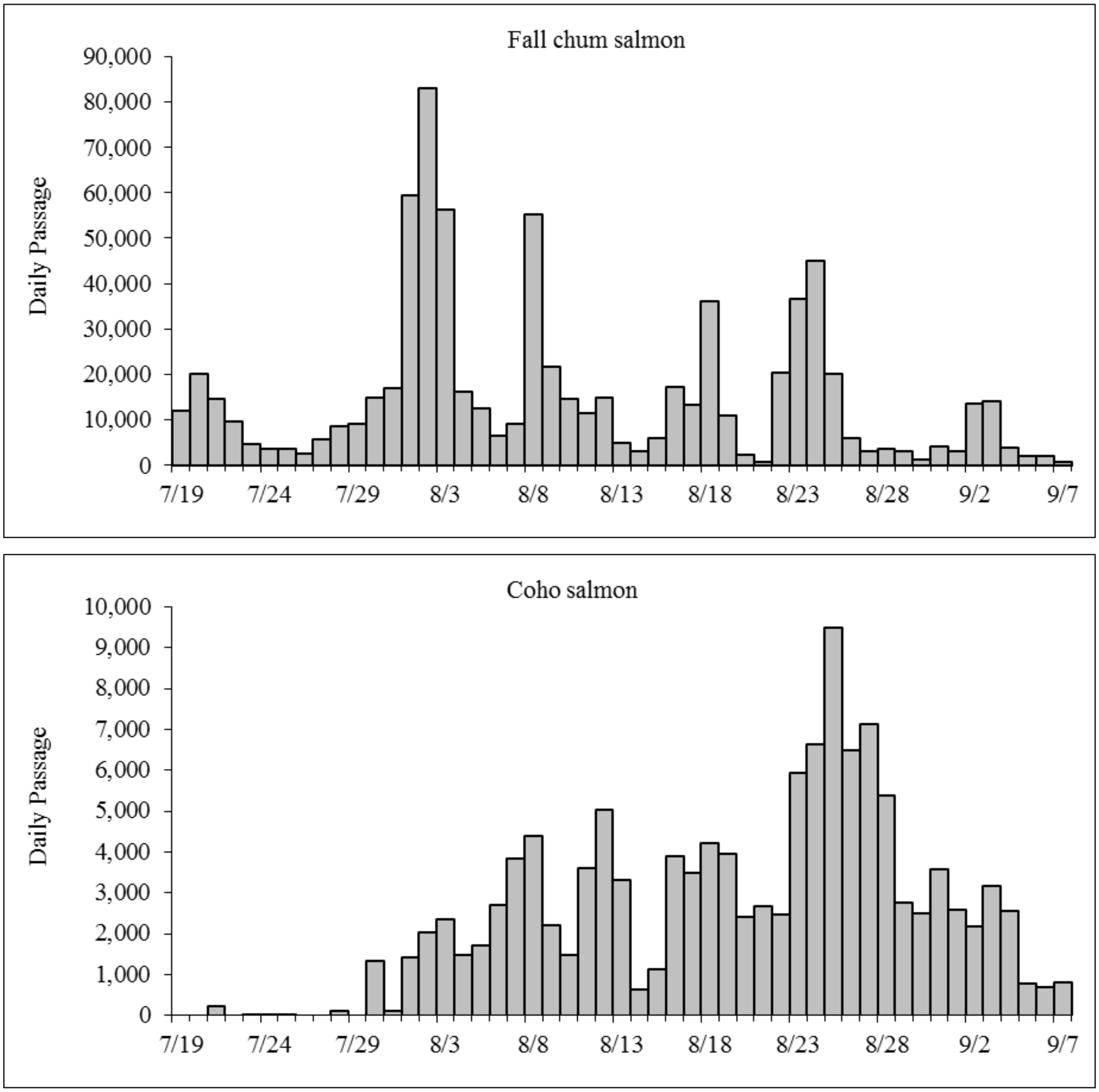


Figure 12.–Fall chum and coho salmon daily passage estimates, at the Pilot Station sonar project on the Yukon River, 2011.

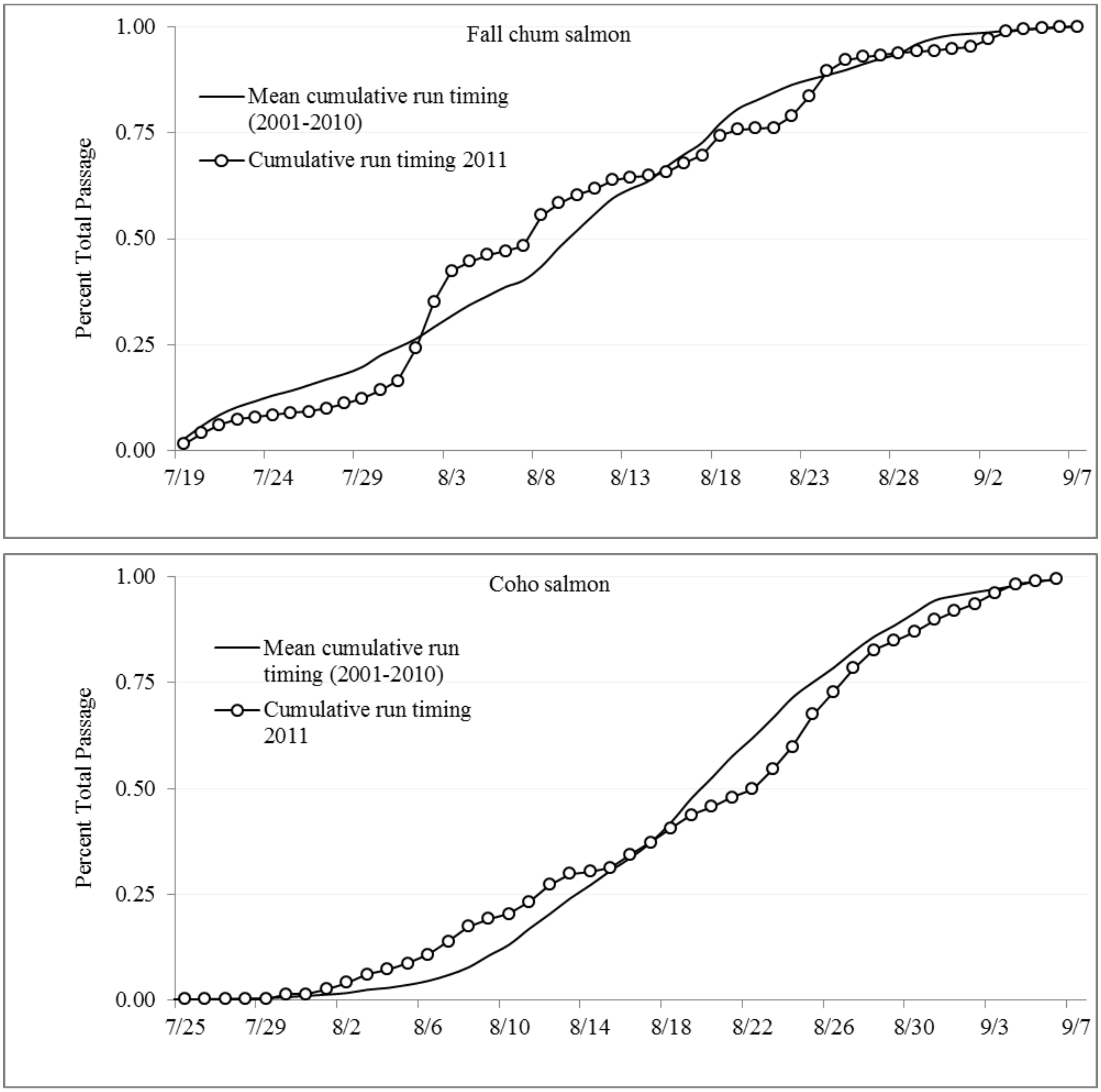
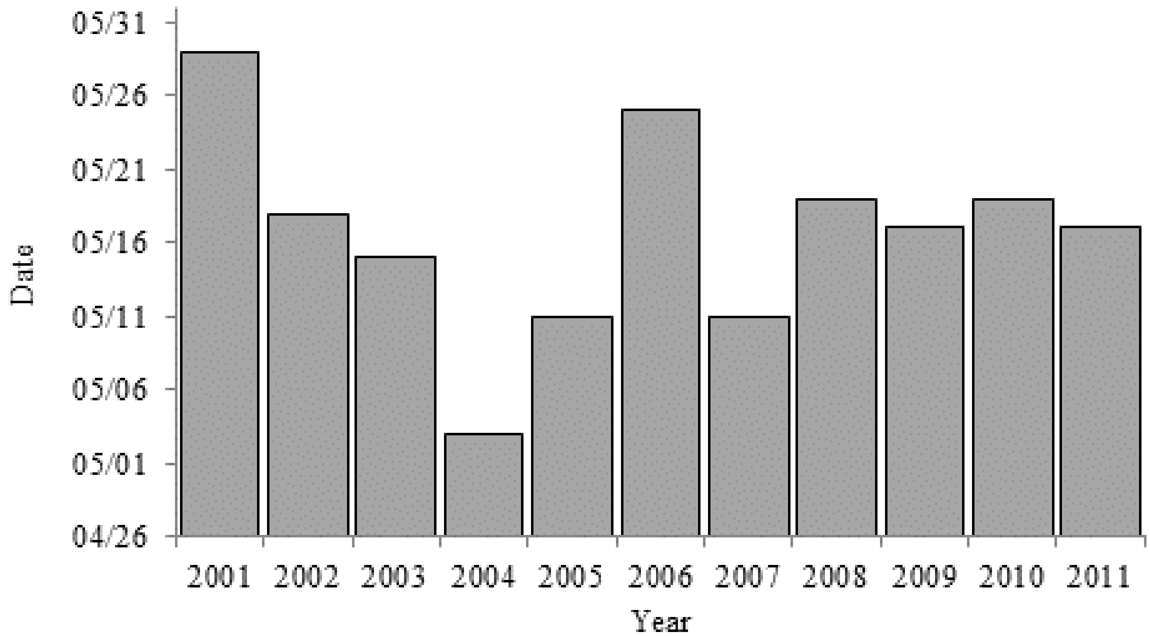
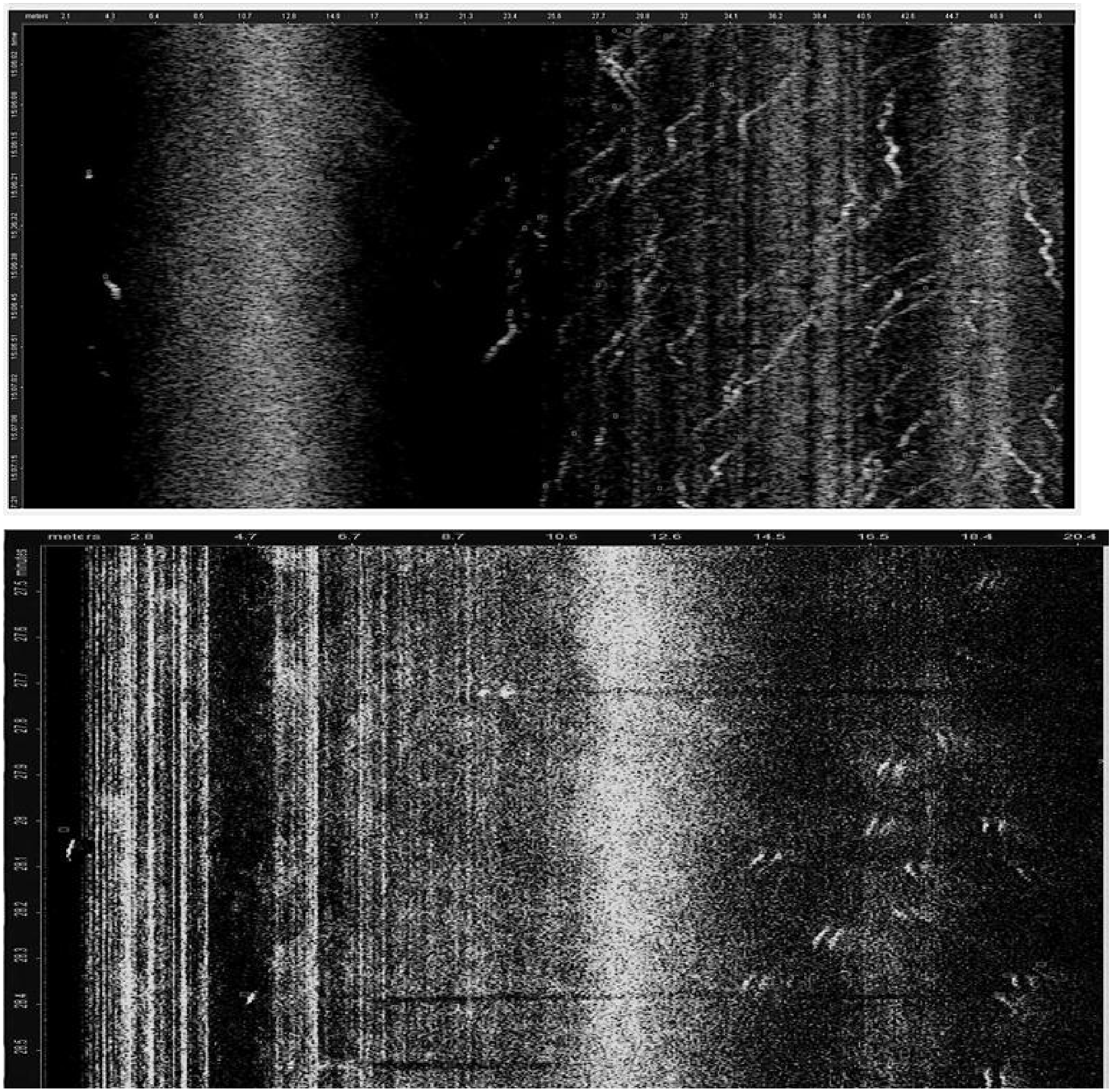


Figure 13.–2011 Fall chum and coho salmon daily cumulative passage timing compared to the 2001–2010 mean passage timing at the Pilot Station sonar project, on the Yukon River.



Source: (NOAA) National Oceanic and Atmospheric Administration. 2012. National Weather Service, Alaska-Pacific River Forecast Center. http//aprfc.arh.noaa.gov/php/brkup/getbrkup.php?riverbasin=Yukon&river=Yukon+River (Accessed: January 25, 2012).

Figure 14.–Yukon River ice breakup dates at Pilot Station.



Note: Echograms illustrate a silt band from approximately 10 to 15 meters from the transducers.

Figure 15.–Split-beam (top) and DIDSON (bottom) echograms collected during the same sampling period on June 19, 2011 at the Pilot Station sonar project on the Yukon River.

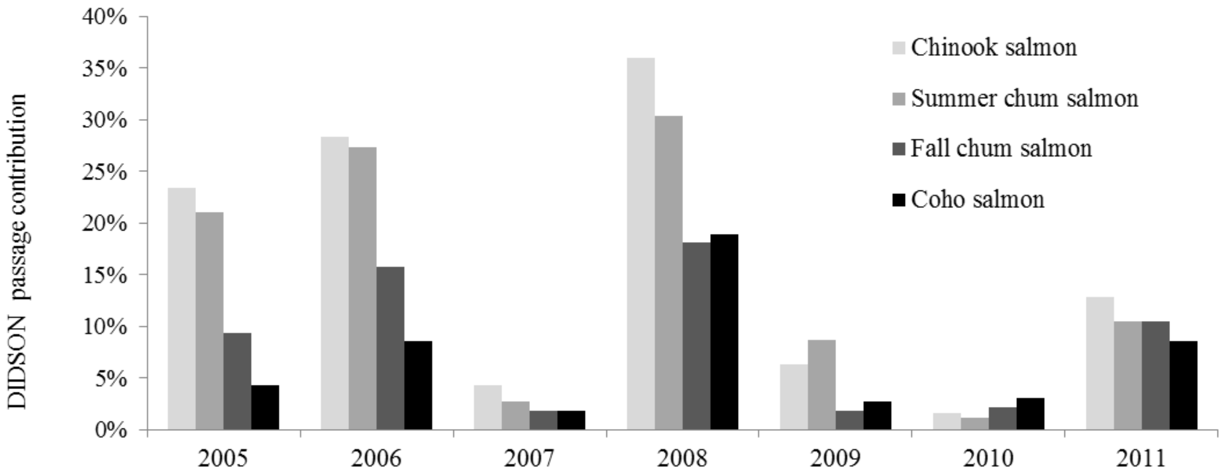


Figure 16.–Percent of additional passage contributed by the DIDSON 2005–2011 at the Pilot Station sonar project, on the Yukon River, relative to split beam in the same area (zone 2, sectors 1 and 2 in stratum 3).

APPENDIX A: NET SELECTIVITY PARAMETERS USED IN FISH SPECIES APPORTIONMENT AT THE PILOT STATION SONAR PROJECT

Appendix A1.–Net selectivity parameters used in fish species apportionment at the Pilot Station sonar project, on the Yukon River, 2011.

Species	Tau	Sigma	Theta	Lambda	Tangle (w)
large Chinook [a]	1.9008	0.2050	0.5923	-0.4334	0.0239
small Chinook [b]	1.9008	0.2050	0.5923	-0.4334	0.0239
summer chum	1.9699	0.1543	0.7504	-0.4841	0.0000
fall chum	1.8632	0.2330	1.1954	-1.4361	0.0303
coho	1.9827	0.3269	0.8686	-1.4557	0.1185
pink	1.9805	0.2598	1.5542	1.2820	0.1649
broad whitefish	1.7774	0.2205	1.4018	-1.9341	0.0981
humpback whitefish	1.9021	0.2320	1.1103	-2.0546	0.0642
cisco	2.0830	0.2223	1.8771	-1.6381	0.1809
other	2.2604	0.3642	0.9881	-2.2990	0.0000

[a] Chinook salmon > 655 mm.

[b] Chinook salmon ≤ 655 mm.

APPENDIX B: SALMON SPECIES CATCH PER UNIT OF EFFORT (CPUE) BY DAY AND BANK

Appendix B1.–Left bank catch per unit of effort (CPUE) by day and salmon species at the Pilot Station sonar project on the Yukon River, 2011.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	Fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
6/01	13.8	1	0.07	7	0	0	0	0	0	0
6/02	20.52	0	0	21.88	0	0	0	0	0	0
6/03	20.5	0	0	19.33	0	0	0	0	0	0
6/04	16.83	1	0.06	18.09	0	0	0	0	0	0
6/05	21.15	1	0.05	20.67	0	0	0	0	0	0
6/06	20.3	3	0.15	21.71	2	0.09	0	0	0	0
6/07	15.72	4	0.25	19.47	5	0.26	0	0	0	0
6/08	20.09	10	0.5	12.27	20	1.63	0	0	0	0
6/09	18.57	4	0.22	11.65	63	5.41	0	0	0	0
6/10	13.23	3	0.23	16.95	35	2.07	0	0	0	0
6/11	16.16	10	0.62	15.58	38	2.44	0	0	0	0
6/12	18.14	8	0.44	13.05	18	1.38	0	0	0	0
6/13	17.21	1	0.06	14.8	25	1.69	0	0	0	0
6/14	5.9	3	0.51	10.94	7	0.64	0	0	0	0
6/15	17.88	2	0.11	17.48	7	0.4	0	0	0	0
6/16	15.3	17	1.11	10.57	38	3.59	0	0	0	0
6/17	8.16	13	1.59	2.9	27	9.31	0	0	0	0
6/18	12.57	20	1.59	6.74	117	17.36	0	0	0	0
6/19	11.82	7	0.59	9.81	88	8.97	0	0	0	0
6/20	17.16	6	0.35	15.86	21	1.32	0	0	0	0
6/21	5.35	5	0.93	10.83	25	2.31	0	0	0	0
6/22	13.6	20	1.47	6.12	68	11.11	0	0	0	0
6/23	11.4	22	1.93	6.03	72	11.93	0	0	0	0
6/24	12.84	25	1.95	7.89	65	8.24	0	0	0	0
6/25	19.43	16	0.82	8.84	61	6.9	0	0	0	0
6/26	17.2	4	0.23	12.22	37	3.03	0	0	0	0
6/27	16.99	1	0.06	16.32	32	1.96	0	0	0	0
6/28	0	0	0	0	0	0	0	0	0	0
6/29	17.87	4	0.22	16.59	15	0.9	0	0	0	0
6/30	16.8	10	0.6	15.5	26	1.68	0	0	0	0
7/01	11.42	2	0.18	6.06	22	3.63	0	0	0	0
7/02	15.63	14	0.9	7.73	60	7.76	0	0	0	0

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Appendix B1.–Page 2 of 3.

Date	Large mesh Fathom hours	Chinook Catch	Chinook CPUE	Small mesh Fathom hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
7/03	15.42	8	0.52	6.94	79	11.39	0	0	0	0
7/04	17.17	10	0.58	8.39	73	8.7	0	0	0	0
7/05	16.78	9	0.54	11.69	42	3.59	0	0	0	0
7/06	16.55	3	0.18	13.14	31	2.36	0	0	0	0
7/07	5.27	0	0	5.81	38	6.55	0	0	0	0
7/08	16.5	1	0.06	13.57	44	3.24	0	0	0	0
7/09	16.31	0	0	11.29	41	3.63	0	0	0	0
7/10	11.43	2	0.18	6.93	33	4.76	0	0	0	0
7/11	10.26	2	0.19	9.58	16	1.67	0	0	0	0
7/12	16.63	0	0	17.33	17	0.98	0	0	0	0
7/13	9.95	3	0.3	10.04	11	1.1	0	0	0	0
7/14	17.75	1	0.06	16.68	13	0.78	0	0	0	0
7/15	5.28	1	0.19	9.86	18	1.83	0	0	0	0
7/16	16.45	0	0	16.8	33	1.96	0	0	0	0
7/17	0	0	0	0	0	0	0	0	0	0
7/18	15.9	1	0.06	15.95	12	0.75	0	0	0	0
7/19	5.36	0	0	16.94	0	0	12	0.71	0	0
7/20	5.13	0	0	14	0	0	19	1.36	0	0
7/21	5.24	0	0	14.73	0	0	19	1.29	1	0.07
7/22	5.65	0	0	15.75	0	0	8	0.51	0	0
7/23	5.91	0	0	15.57	0	0	7	0.45	0	0
7/24	0	0	0	23.35	0	0	7	0.3	0	0
7/25	0	0	0	23.01	0	0	5	0.22	0	0
7/26	5.39	0	0	16.8	0	0	4	0.24	0	0
7/27	5.28	0	0	16.52	0	0	8	0.48	0	0
7/28	5.52	0	0	16.13	0	0	20	1.24	0	0
7/29	5.49	0	0	16.01	0	0	15	0.94	0	0
7/30	5.9	0	0	14.1	0	0	16	1.13	3	0.21
7/31	5.61	0	0	15.53	0	0	36	2.32	0	0
8/01	5.5	0	0	8.61	0	0	53	6.15	2	0.23
8/02	5.22	0	0	10.73	0	0	79	7.37	0	0
8/03	4.69	0	0	7.94	0	0	46	5.79	1	0.13
8/04	5.51	1	0.18	13.4	0	0	46	3.43	2	0.15

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Appendix B1.–Page 3 of 3.

Date	Large mesh Fathom hours	Chinook Catch	Chinook CPUE	Small mesh Fathom hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
8/05	5.59	0	0	16.46	0	0	25	1.52	1	0.06
8/06	6.27	0	0	11.18	0	0	9	0.81	0	0
8/07	5.55	0	0	17.1	0	0	16	0.94	8	0.47
8/08	4.76	0	0	11.05	0	0	47	4.25	4	0.36
8/09	3.18	0	0	5.82	0	0	34	5.85	2	0.34
8/10	5.5	0	0	13.47	0	0	13	0.97	3	0.22
8/11	5.62	0	0	14.39	0	0	27	1.88	5	0.35
8/12	5.7	0	0	15.82	0	0	33	2.09	4	0.25
8/13	5.25	0	0	17.27	0	0	12	0.69	11	0.64
8/14	6.37	0	0	11.36	0	0	0	0	1	0.09
8/15	5.06	0	0	16.94	0	0	24	1.42	2	0.12
8/16	5.35	0	0	11.13	0	0	36	3.23	7	0.63
8/17	5.35	0	0	10.16	0	0	8	0.79	3	0.3
8/18	5.05	0	0	12.11	0	0	47	3.88	1	0.08
8/19	5.51	0	0	15.75	0	0	19	1.21	7	0.44
8/20	6.73	0	0	16.81	0	0	4	0.24	6	0.36
8/21	6.28	0	0	17.15	0	0	1	0.06	5	0.29
8/22	4.99	0	0	13.81	0	0	36	2.61	4	0.29
8/23	4.3	0	0	4.83	0	0	29	6	2	0.41
8/24	4.45	0	0	7.53	0	0	38	5.05	6	0.8
8/25	4.85	0	0	14.23	0	0	25	1.76	10	0.7
8/26	6.27	0	0	13.63	0	0	11	0.81	14	1.03
8/27	6.14	0	0	16.97	0	0	4	0.24	7	0.41
8/28	5.28	0	0	17.3	0	0	4	0.23	14	0.81
8/29	5.91	0	0	15.24	0	0	3	0.2	4	0.26
8/30	4.93	0	0	15.07	0	0	4	0.27	3	0.2
8/31	5.81	0	0	17.36	0	0	4	0.23	6	0.35
9/01	6.02	0	0	16.75	0	0	7	0.42	5	0.3
9/02	6.08	0	0	17.49	0	0	12	0.69	0	0
9/03	5.43	0	0	15.95	0	0	21	1.32	6	0.38
9/04	6.18	0	0	17.25	0	0	6	0.35	5	0.29
9/05	5.77	0	0	16.23	0	0	4	0.25	1	0.06
9/06	5.44	0	0	17.28	0	0	6	0.35	0	0
9/07	6.31	0	0	15.67	0	0	2	0.13	2	0.13
Total	955.87	279		1,320.56	1,495		971	84.67	168	

Appendix B2.–Right bank catch per unit of effort (CPUE) by day and salmon species at the Pilot Station sonar project on the Yukon River, 2011.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	Fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
6/01	4.82	0	0.00	2.22	0	0.00	0	0.00	0	0.00
6/02	7.63	0	0.00	0.00	0	0.00	0	0.00	0	0.00
6/03	4.48	0	0.00	5.52	0	0.00	0	0.00	0	0.00
6/04	7.03	0	0.00	7.08	0	0.00	0	0.00	0	0.00
6/05	8.16	0	0.00	7.24	0	0.00	0	0.00	0	0.00
6/06	7.57	0	0.00	6.56	0	0.00	0	0.00	0	0.00
6/07	5.01	0	0.00	8.42	0	0.00	0	0.00	0	0.00
6/08	3.99	3	0.75	2.88	0	0.00	0	0.00	0	0.00
6/09	8.75	2	0.23	5.66	9	1.59	0	0.00	0	0.00
6/10	4.39	0	0.00	6.34	2	0.32	0	0.00	0	0.00
6/11	6.79	0	0.00	5.72	1	0.17	0	0.00	0	0.00
6/12	6.71	1	0.15	6.11	2	0.33	0	0.00	0	0.00
6/13	7.13	1	0.14	7.11	9	1.27	0	0.00	0	0.00
6/14	2.52	0	0.00	3.94	1	0.25	0	0.00	0	0.00
6/15	7.76	0	0.00	7.78	3	0.39	0	0.00	0	0.00
6/16	7.07	0	0.00	8.40	5	0.60	0	0.00	0	0.00
6/17	3.76	0	0.00	1.38	15	10.88	0	0.00	0	0.00
6/18	6.59	2	0.30	3.74	32	8.56	0	0.00	0	0.00
6/19	4.69	2	0.43	5.04	7	1.39	0	0.00	0	0.00
6/20	6.89	0	0.00	7.47	13	1.74	0	0.00	0	0.00
6/21	2.18	0	0.00	4.75	21	4.42	0	0.00	0	0.00
6/22	5.64	0	0.00	3.26	51	15.64	0	0.00	0	0.00
6/23	5.87	2	0.34	3.15	38	12.08	0	0.00	0	0.00
6/24	7.09	3	0.42	4.24	33	7.79	0	0.00	0	0.00
6/25	7.51	2	0.27	4.40	42	9.55	0	0.00	0	0.00
6/26	6.93	2	0.29	6.01	34	5.66	0	0.00	0	0.00
6/27	7.94	1	0.13	6.89	30	4.35	0	0.00	0	0.00
6/28	0.00	0	0.00	0.00	0	0.00	0	0.00	0	0.00
6/29	7.26	2	0.28	7.50	34	4.53	0	0.00	0	0.00
6/30	7.57	2	0.26	4.28	64	14.95	0	0.00	0	0.00
7/01	5.24	1	0.19	2.34	19	8.12	0	0.00	0	0.00
7/02	7.15	1	0.14	2.44	41	16.82	0	0.00	0	0.00

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Date	Large mesh Fathom hours	Chinook Catch	Chinook CPUE	Small mesh Fathom hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
7/03	7.54	1	0.13	2.45	58	23.69	0	0.00	0	0.00
7/04	7.47	4	0.54	3.26	68	20.86	0	0.00	0	0.00
7/05	6.40	2	0.31	4.41	45	10.21	0	0.00	0	0.00
7/06	6.75	4	0.59	3.63	18	4.96	0	0.00	0	0.00
7/07	2.39	0	0.00	2.19	19	8.69	0	0.00	0	0.00
7/08	7.08	3	0.42	5.46	29	5.31	0	0.00	0	0.00
7/09	7.49	3	0.40	3.68	31	8.42	0	0.00	0	0.00
7/10	4.78	0	0.00	2.18	10	4.58	0	0.00	0	0.00
7/11	5.21	1	0.19	5.01	21	4.19	0	0.00	0	0.00
7/12	7.47	2	0.27	7.97	34	4.27	0	0.00	0	0.00
7/13	5.01	2	0.40	4.57	17	3.72	0	0.00	0	0.00
7/14	8.23	1	0.12	7.07	15	2.12	0	0.00	0	0.00
7/15	2.71	1	0.37	4.03	19	4.71	0	0.00	0	0.00
7/16	7.81	0	0.00	6.64	51	7.68	0	0.00	0	0.00
7/17	0.00	0	0.00	0.00	0	0.00	0	0.00	0	0.00
7/18	7.96	1	0.13	6.64	17	2.56	0	0.00	0	0.00
7/19	2.26	0	0.00	7.55	0	0.00	11	1.46	0	0.00
7/20	2.25	0	0.00	6.47	0	0.00	11	1.70	0	0.00
7/21	2.61	0	0.00	7.44	0	0.00	11	1.48	0	0.00
7/22	2.11	0	0.00	7.93	0	0.00	7	0.88	0	0.00
7/23	2.66	0	0.00	7.14	0	0.00	5	0.70	0	0.00
7/24	0.00	0	0.00	10.69	0	0.00	6	0.56	0	0.00
7/25	0.00	0	0.00	11.48	0	0.00	3	0.26	1	0.09
7/26	2.96	0	0.00	7.58	0	0.00	3	0.40	0	0.00
7/27	2.59	0	0.00	7.54	0	0.00	9	1.19	0	0.00
7/28	2.65	0	0.00	7.34	0	0.00	11	1.50	0	0.00
7/29	2.61	0	0.00	7.76	0	0.00	3	0.39	0	0.00
7/30	2.76	0	0.00	6.60	0	0.00	16	2.43	0	0.00
7/31	2.29	0	0.00	7.83	0	0.00	20	2.55	1	0.13
8/01	2.30	0	0.00	3.86	0	0.00	40	10.36	1	0.26
8/02	2.91	0	0.00	3.19	0	0.00	35	10.96	0	0.00
8/03	2.43	0	0.00	5.35	0	0.00	27	5.05	2	0.37
8/04	2.86	0	0.00	6.44	0	0.00	4	0.62	0	0.00

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	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	Fathom hours	Catch	CPUE	Fathom hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
8/05	2.50	0	0.00	8.35	0	0.00	15	1.80	5	0.60
8/06	2.52	0	0.00	4.80	0	0.00	2	0.42	1	0.21
8/07	2.90	1	0.34	8.67	0	0.00	19	2.19	7	0.81
8/08	2.42	0	0.00	5.06	0	0.00	37	7.32	1	0.20
8/09	2.06	0	0.00	3.49	0	0.00	14	4.01	3	0.86
8/10	2.52	0	0.00	6.90	0	0.00	12	1.74	3	0.43
8/11	2.78	0	0.00	7.02	0	0.00	11	1.57	0	0.00
8/12	2.59	0	0.00	7.09	0	0.00	12	1.69	2	0.28
8/13	2.63	0	0.00	8.43	0	0.00	4	0.47	8	0.95
8/14	2.23	0	0.00	5.41	0	0.00	1	0.18	0	0.00
8/15	2.65	0	0.00	7.91	0	0.00	11	1.39	4	0.51
8/16	2.55	0	0.00	6.76	0	0.00	15	2.22	3	0.44
8/17	2.52	0	0.00	5.04	0	0.00	13	2.58	6	1.19
8/18	2.63	0	0.00	6.38	0	0.00	36	5.65	2	0.31
8/19	2.16	0	0.00	6.54	0	0.00	5	0.76	7	1.07
8/20	2.16	0	0.00	7.79	0	0.00	6	0.77	13	1.67
8/21	2.59	0	0.00	8.95	0	0.00	2	0.22	8	0.89
8/22	2.61	0	0.00	5.39	0	0.00	29	5.38	3	0.56
8/23	2.45	0	0.00	2.14	0	0.00	10	4.68	3	1.40
8/24	2.02	0	0.00	4.10	0	0.00	14	3.41	5	1.22
8/25	2.15	0	0.00	6.22	0	0.00	17	2.74	15	2.41
8/26	2.99	0	0.00	5.52	0	0.00	9	1.63	19	3.44
8/27	2.59	0	0.00	6.81	0	0.00	7	1.03	18	2.64
8/28	2.46	0	0.00	7.77	0	0.00	5	0.64	9	1.16
8/29	2.80	0	0.00	7.35	0	0.00	3	0.41	12	1.63
8/30	2.91	0	0.00	7.51	0	0.00	1	0.13	9	1.20
8/31	2.88	0	0.00	8.21	0	0.00	14	1.70	5	0.61
9/01	2.56	0	0.00	8.15	0	0.00	7	0.86	9	1.10
9/02	2.61	0	0.00	7.87	0	0.00	23	2.92	7	0.89
9/03	2.84	0	0.00	7.85	0	0.00	14	1.78	7	0.89
9/04	2.83	0	0.00	7.27	0	0.00	2	0.27	5	0.69
9/05	2.90	0	0.00	7.60	0	0.00	7	0.92	4	0.53
9/06	2.62	0	0.00	6.51	0	0.00	5	0.77	6	0.92
9/07	2.35	0	0.00	7.53	0	0.00	4	0.53	3	0.40
Total	411.65	53		577.64	958		608		217	

APPENDIX C: DAILY FISH PASSAGE ESTIMATES BY ZONE WITH STANDARD ERRORS

Appendix C1.–Daily passage estimates by zone with standard errors (SE), at the Pilot Station sonar project on the Yukon River, 2011.

		Left Bank				Percent by bank	
Date	Right Bank	Nearshore	Offshore	Total	SE	Right	Left
6/01	2,367	ND	ND	2,367	1,096	100.00	0.00
6/02	990	ND	ND	990	709	100.00	0.00
6/03	ND	ND	ND	ND	ND	ND	ND
6/04	1,086	1,612	55	2,753	408	39.45	60.55
6/05	1,478	1,500	153	3,131	640	47.21	52.79
6/06	946	1,653	144	2,743	483	34.49	65.51
6/07	1,253	2,487	136	3,876	1,180	32.33	67.67
6/08	2,614	5,408	7	8,029	1,724	32.56	67.44
6/09	3,713	12,239	144	16,096	2,535	23.07	76.93
6/10	1,699	11,357	2,033	15,089	1,386	11.26	88.74
6/11	1,450	8,781	2,147	12,378	1,918	11.71	88.29
6/12	2,747	5,565	1,266	9,578	1,237	28.68	71.32
6/13	2,703	4,752	1,146	8,601	2,795	31.43	68.57
6/14	2,342	5,229	1,195	8,766	1,741	26.72	73.28
6/15	2,322	4,504	1,152	7,978	1,631	29.11	70.89
6/16	6,928	13,391	1,881	22,200	5,598	31.21	68.79
6/17	18,344	60,046	13,134	91,524	8,792	20.04	79.96
6/18	19,005	75,380	23,591	117,976	10,102	16.11	83.89
6/19	8,931	25,762	11,595	46,288	13,238	19.29	80.71
6/20	6,559	7,931	6,860	21,350	2,683	30.72	69.28
6/21	5,963	8,541	8,086	22,590	2,775	26.40	73.60
6/22	58,623	96,808	24,168	179,599	26,495	32.64	67.36
6/23	83,526	125,848	42,687	252,061	14,083	33.14	66.86
6/24	68,038	75,282	31,964	175,284	9,154	38.82	61.18
6/25	38,806	30,307	12,380	81,493	9,713	47.62	52.38
6/26	15,686	10,336	10,745	36,767	3,968	42.66	57.34
6/27	6,721	6,219	5,153	18,093	3,089	37.15	62.85
6/28	4,884	4,223	4,039	13,146	2,662	37.15	62.85
6/29	6,191	5,652	6,242	18,085	1,938	34.23	65.77
6/30	20,401	21,069	14,303	55,773	10,465	36.58	63.42
7/01	24,261	32,681	21,348	78,290	7,326	30.99	69.01
7/02	48,220	50,426	24,897	123,543	9,452	39.03	60.97
7/03	81,833	91,019	38,487	211,339	26,098	38.72	61.28
7/04	43,212	70,216	18,319	131,747	8,624	32.80	67.20
7/05	25,477	34,526	9,943	69,946	8,931	36.42	63.58
7/06	14,775	40,843	8,991	64,609	7,323	22.87	77.13
7/07	17,499	35,232	6,402	59,133	6,701	29.59	70.41
7/08	17,520	33,766	4,455	55,741	6,501	31.43	68.57
7/09	18,207	34,025	4,279	56,511	2,880	32.22	67.78
7/10	13,329	16,235	2,593	32,157	4,665	41.45	58.55
7/11	9,733	8,003	2,966	20,702	3,466	47.01	52.99
7/12	7,982	8,509	2,780	19,271	4,036	41.42	58.58
7/13	6,640	5,378	2,268	14,286	3,590	46.48	53.52
7/14	6,204	5,004	1,659	12,867	3,020	48.22	51.78
7/15	8,948	7,228	2,636	18,812	3,680	47.57	52.43
7/16	11,394	19,111	4,263	34,768	5,571	32.77	67.23
7/17	12,487	12,694	6,555	31,736	4,991	39.35	60.65
7/18	7,509	9,671	3,814	20,994	7,188	35.77	64.23
7/19	5,185	9,661	2,901	17,747	2,204	29.22	70.78
7/20	5,755	12,144	3,069	20,968	888	27.45	72.55

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Appendix C1.–Page 2 of 2.

Date	Right Bank	Left Bank		Total	SE	Percent by bank	
		Nearshore	Offshore			Right	Left
7/21	5,100	9,609	3,077	17,786	1,278	28.67	71.33
7/22	4,151	7,205	2,027	13,383	2,170	31.02	68.98
7/23	2,859	5,804	1,603	10,266	1,224	27.85	72.15
7/24	2,207	5,559	697	8,463	1,075	26.08	73.92
7/25	1,786	6,190	865	8,841	1,126	20.20	79.80
7/26	3,402	8,155	1,202	12,759	3,945	26.66	73.34
7/27	4,167	10,250	1,971	16,388	2,356	25.43	74.57
7/28	5,930	12,706	3,598	22,234	4,662	26.67	73.33
7/29	3,061	10,524	2,548	16,133	2,124	18.97	81.03
7/30	5,248	14,606	4,535	24,389	5,781	21.52	78.48
7/31	7,542	17,316	5,072	29,930	4,409	25.20	74.80
8/01	17,162	36,325	20,489	73,976	11,402	23.20	76.80
8/02	25,855	45,634	32,293	103,782	13,806	24.91	75.09
8/03	12,608	33,656	19,528	65,792	4,741	19.16	80.84
8/04	5,342	14,747	9,232	29,321	11,946	18.22	81.78
8/05	5,988	11,817	6,149	23,954	4,482	25.00	75.00
8/06	5,423	8,837	5,425	19,685	5,310	27.55	72.45
8/07	7,243	12,610	7,789	27,642	6,292	26.20	73.8
8/08	15,805	36,094	14,375	66,274	5,502	23.85	76.15
8/09	8,489	15,120	12,131	35,740	7,147	23.75	76.25
8/10	5,239	10,494	8,084	23,817	5,937	22.00	78.00
8/11	4,648	10,828	4,936	20,412	3,369	22.77	77.23
8/12	7,123	13,265	5,371	25,759	5,539	27.65	72.35
8/13	4,538	7,042	4,504	16,084	2,007	28.21	71.79
8/14	4,015	3,895	2,948	10,858	3,474	36.98	63.02
8/15	5,420	7,062	6,051	18,533	4,744	29.25	70.75
8/16	10,615	13,604	9,840	34,059	8,328	31.17	68.83
8/17	12,606	8,284	8,926	29,816	7,854	42.28	57.72
8/18	11,990	17,765	20,658	50,413	6,235	23.78	76.22
8/19	9,143	10,103	9,856	29,102	4,282	31.42	68.58
8/20	5,617	5,801	3,438	14,856	2,507	37.81	62.19
8/21	4,090	4,631	2,749	11,470	2,360	35.66	64.34
8/22	18,398	18,870	9,744	47,012	9,685	39.13	60.87
8/23	19,349	24,378	27,958	71,685	17,247	26.99	73.01
8/24	11,282	24,534	41,067	76,883	17,571	14.67	85.33
8/25	9,149	12,842	14,697	36,688	4,264	24.94	75.06
8/26	5,897	9,525	8,574	23,996	2,801	24.57	75.43
8/27	6,252	7,053	5,608	18,913	4,262	33.06	66.94
8/28	5,963	5,963	4,415	16,341	1,741	36.49	63.51
8/29	4,145	4,700	3,173	12,018	2,637	34.49	65.51
8/30	3,286	4,276	2,500	10,062	2,784	32.66	67.34
8/31	3,874	4,673	2,476	11,023	2,267	35.14	64.86
9/01	4,377	5,005	3,205	12,587	3,688	34.77	65.23
9/02	9,096	8,672	7,436	25,204	3,966	36.09	63.91
9/03	9,157	8,768	7,341	25,266	5,258	36.24	63.76
9/04	5,967	5,840	4,319	16,126	3,260	37.00	63.00
9/05	4,777	3,154	2,020	9,951	1,368	48.01	51.99
9/06	4,777	3,242	1,442	9,461	1,742	50.49	49.51
9/07	3,076	2,522	1,026	6,624	1,195	46.44	53.56
Total	1,145,720	1,757,809	787,999	3,691,528		31.04	68.96

APPENDIX D: DAILY FISH PASSAGE ESTIMATES BY SPECIES

Appendix D1.–Daily fish passage estimates by species at the Pilot Station sonar project on the Yukon River, 2011.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
6/01	0	0	0	0	0	0	0	2,367	2,367
6/02	0	0	0	0	0	0	0	990	990
6/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/04	112	0	112	0	0	0	0	2,641	2,753
6/05	169	0	169	0	0	0	0	2,962	3,131
6/06	505	0	505	79	0	0	0	2,159	2,743
6/07	532	200	732	1,693	0	0	0	1,451	3,876
6/08	1,086	435	1,521	3,453	0	0	0	3,055	8,029
6/09	663	279	942	14,125	0	0	0	1,029	16,096
6/10	1,120	154	1,274	12,998	0	0	0	817	15,089
6/11	1,103	67	1,170	8,158	0	0	0	3,050	12,378
6/12	918	254	1,172	6,540	0	0	0	1,866	9,578
6/13	141	69	210	5,241	0	0	0	3,150	8,601
6/14	311	413	724	2,936	0	0	0	5,106	8,766
6/15	291	370	661	2,682	0	0	0	4,635	7,978
6/16	3,371	371	3,742	14,715	0	0	0	3,743	22,200
6/17	5,124	701	5,825	84,452	0	0	0	1,247	91,524
6/18	6,962	932	7,894	108,401	0	0	0	1,681	117,976
6/19	3,853	434	4,287	41,552	0	0	0	449	46,288
6/20	2,017	1,339	3,356	16,413	0	0	0	1,581	21,350
6/21	2,270	1,453	3,723	17,286	0	0	0	1,581	22,590
6/22	11,395	1,477	12,872	165,767	0	0	0	960	179,599
6/23	11,198	1,961	13,159	238,113	0	0	0	789	252,061
6/24	10,182	1,313	11,495	162,967	0	0	0	822	175,284
6/25	2,902	2,317	5,219	73,462	0	0	0	2,812	81,493
6/26	1,366	1,448	2,814	33,351	0	0	0	602	36,767
6/27	518	247	765	14,905	0	0	0	2,423	18,093
6/28	367	171	538	10,769	0	0	0	1,839	13,146
6/29	1,697	73	1,770	15,132	0	0	0	1,183	18,085
6/30	3,928	943	4,871	45,864	0	0	0	5,038	55,773
7/01	2,934	693	3,627	70,380	0	0	0	4,283	78,290
7/02	4,165	978	5,143	111,209	0	0	0	7,191	123,543
7/03	3,364	1,156	4,520	184,405	0	0	0	22,414	211,339
7/04	3,052	0	3,052	117,432	0	0	0	11,263	131,747
7/05	2,085	1,433	3,518	54,676	0	0	0	11,752	69,946
7/06	1,779	125	1,904	51,117	0	0	0	11,588	64,609
7/07	789	75	864	48,644	0	0	0	9,625	59,133
7/08	780	75	855	46,100	0	0	0	8,786	55,741
7/09	371	0	371	50,944	0	0	0	5,196	56,511
7/10	569	96	665	22,241	0	189	0	9,062	32,157
7/11	300	70	370	13,810	0	138	0	6,384	20,702
7/12	813	184	997	10,332	0	192	0	7,750	19,271
7/13	612	132	744	7,592	0	121	0	5,829	14,286
7/14	289	0	289	8,726	0	0	0	3,852	12,867
7/15	422	0	422	12,682	0	0	0	5,708	18,812
7/16	235	66	301	29,132	0	0	0	5,335	34,768

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	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
7/17	180	72	252	26,798	0	0	0	4,686	31,736
7/18	336	0	336	10,534	0	0	0	10,124	20,994
7/19	0	0	0	0	11,948	438	0	5,361	17,747
7/20	0	0	0	0	20,209	0	0	759	20,968
7/21	605	243	848	0	14,626	0	222	2,090	17,786
7/22	1,143	67	1,210	0	9,547	122	0	2,504	13,383
7/23	126	0	126	0	4,609	473	24	5,034	10,266
7/24	121	0	121	0	3,513	411	19	4,399	8,463
7/25	135	0	135	0	3,645	403	15	4,643	8,841
7/26	0	98	98	0	2,554	371	0	9,736	12,759
7/27	0	0	0	0	5,682	0	0	10,706	16,388
7/28	0	0	0	0	8,576	392	113	13,153	22,234
7/29	0	0	0	0	9,163	0	0	6,970	16,133
7/30	0	0	0	0	14,785	0	1,337	8,267	24,389
7/31	363	168	531	0	17,037	292	97	11,973	29,930
8/01	0	0	0	0	59,295	645	1,422	12,614	73,976
8/02	0	0	0	0	83,067	810	2,024	17,881	103,782
8/03	0	0	0	0	56,242	323	2,360	6,867	65,792
8/04	347	0	347	0	16,233	0	1,488	11,253	29,321
8/05	0	0	0	0	12,521	539	1,708	9,186	23,954
8/06	86	0	86	0	6,505	79	2,706	10,309	19,685
8/07	115	0	115	0	9,195	105	3,828	14,399	27,642
8/08	0	0	0	0	55,353	0	4,380	6,541	66,274
8/09	0	0	0	0	21,704	0	2,195	11,841	35,740
8/10	0	0	0	0	14,647	0	1,466	7,704	23,817
8/11	0	0	0	0	11,572	0	3,612	5,228	20,412
8/12	0	0	0	0	14,983	190	5,025	5,561	25,759
8/13	0	0	0	0	4,947	0	3,319	7,818	16,084
8/14	0	0	0	0	3,183	0	629	7,046	10,858
8/15	0	0	0	0	5,968	0	1,124	11,441	18,533
8/16	0	0	0	0	17,132	0	3,887	13,040	34,059
8/17	0	0	0	0	13,396	0	3,477	12,943	29,816
8/18	0	0	0	0	36,144	0	4,206	10,063	50,413
8/19	0	0	0	0	10,815	58	3,966	14,263	29,102
8/20	0	0	0	0	2,351	0	2,410	10,095	14,856
8/21	0	0	0	0	723	0	2,675	8,072	11,470
8/22	0	0	0	0	20,446	0	2,459	24,107	47,012
8/23	0	0	0	0	36,560	117	5,942	29,066	71,685
8/24	0	0	0	0	45,028	118	6,637	25,100	76,883
8/25	0	0	0	0	20,060	0	9,478	7,150	36,688
8/26	0	0	0	0	6,043	0	6,478	11,475	23,996
8/27	0	0	0	0	3,060	0	7,140	8,713	18,913
8/28	0	0	0	0	3,497	0	5,388	7,456	16,341
8/29	0	0	0	0	3,038	0	2,770	6,210	12,018
8/30	0	0	0	0	1,185	0	2,510	6,367	10,062
8/31	0	0	0	0	4,168	0	3,585	3,270	11,023

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	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
9/01	0	0	0	0	2,984	0	2,592	7,011	12,587
9/02	0	0	0	0	13,612	0	2,185	9,407	25,204
9/03	0	0	0	0	14,002	0	3,171	8,093	25,266
9/04	0	0	0	0	3,973	0	2,563	9,590	16,126
9/05	0	0	0	0	1,962	0	788	7,201	9,951
9/06	0	0	0	0	2,016	0	705	6,740	9,461
9/07	0	0	0	0	690	0	806	5,128	6,624
Total	100,217	23,152	123,369	1,977,808	764,194	6,526	124,931	694,700	3,691,528

[a] Chinook salmon > 655 mm.

[b] Chinook salmon ≤ 655mm.

APPENDIX E: PILOT STATION SONAR FISH PASSAGE ESTIMATES, 2001–2011

Appendix E1.–Pilot Station sonar project total fish passage estimates by species, 2001–2011.

Species	2011	2010	2009[a]	2008	2007	2006	2005[b]	2004	2003	2002	2001[c]
Large Chinook[d]	100,217	100,699	108,361	106,708	90,184	145,553	142,007	110,236	245,037	92,584	85,511
Small Chinook	23,152	19,476	35,688	23,935	35,369	23,850	17,434	46,370	23,500	30,629	13,892
Chinook Total	123,369	120,175	144,049	130,643	125,553	169,403	159,441	156,606	268,537	123,213	99,403
Summer chum	1,977,808	1,405,533	1,421,646	1,665,667	1,726,885	3,767,044	2,439,616	1,357,826	1,168,518	1,088,463	441,450
Fall chum[e]	764,194	393,326	233,307	615,127	684,011	790,563	1,813,589	594,060	889,778	326,858	376,182
Total chum	2,742,002	1,798,859	1,654,953	2,280,794	2,410,896	4,557,607	4,253,205	1,951,886	2,058,296	1,415,321	817,632
Coho[e]	124,931	155,784	206,620	135,570	173,289	131,919	184,718	188,350	269,081	122,566	137,769
Pink	6,526	747,297	23,679	558,050	71,699	115,624	37,932	243,375	4,656	64,891	665
Other Species[f]	694,700	862,034	765,140	585,303	1,085,316	875,899	593,248	637,257	502,878	557,779	353,431
Season Total	3,691,528	3,684,149	2,794,441	3,690,360	3,866,753	5,850,452	5,228,544	3,177,474	3,103,448	2,283,770	1,408,900

Note: Estimates for all years were generated with the most current apportionment model and may differ from earlier estimates.

[a] High water levels were experienced at Pilot Station in 2009, and therefore passage estimates are considered conservative.

[b] Estimates include extrapolations for the dates June 10 to June 18, 2005, to account for the time before the DIDSON was deployed.

[c] High water levels were experienced at Pilot Station in 2001, and therefore passage estimates are considered conservative.

[d] Chinook salmon >655 mm.

[e] This estimate may not include the entire run; however, starting in 2008, operations were extended to September 7, instead of the usual end date of August 31.

[f] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, suckers, Dolly Varden, and northern pike.

APPENDIX F: DIDSON-GENERATED COMPONENT AND PROPORTIONS OF THE LEFT BANK NEARSHORE DAILY FISH PASSAGE ESTIMATES

Appendix F1.–DIDSON-generated component of the left bank nearshore daily fish passage estimates at the Pilot Station sonar project on the Yukon River, 2011.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
6/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/02	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/04	19	0	19	0	0	0	0	448	467
6/05	48	0	48	0	0	0	0	1,120	1,168
6/06	253	0	253	0	0	0	0	759	1,012
6/07	146	92	238	733	0	0	0	179	1,150
6/08	400	254	654	2,012	0	0	0	491	3,156
6/09	249	155	404	6,359	0	0	0	51	6,814
6/10	590	94	684	6,029	0	0	0	202	6,915
6/11	455	0	455	3,533	0	0	0	1,142	5,131
6/12	293	46	339	1,952	0	0	0	0	2,291
6/13	0	0	0	908	0	0	0	875	1,783
6/14	28	88	116	518	0	0	0	1,080	1,714
6/15	36	114	150	670	0	0	0	1,395	2,215
6/16	595	70	664	2,216	0	0	0	398	3,278
6/17	572	87	659	7,850	0	0	0	149	8,657
6/18	759	116	875	10,417	0	0	0	197	11,489
6/19	314	86	400	4,682	0	0	0	29	5,110
6/20	116	123	238	715	0	0	0	37	990
6/21	136	144	279	839	0	0	0	43	1,161
6/22	2,154	242	2,396	18,144	0	0	0	114	20,654
6/23	1,216	207	1,422	15,013	0	0	0	0	16,435
6/24	261	79	340	4,175	0	0	0	0	4,514
6/25	66	31	96	1,319	0	0	0	92	1,507
6/26	16	26	42	502	0	0	0	18	563
6/27	17	9	25	255	0	0	0	16	296
6/28	23	12	36	362	0	0	0	22	420
6/29	107	0	107	566	0	0	0	0	673
6/30	156	47	203	865	0	0	0	70	1,138
7/01	324	87	411	5,330	0	0	0	575	6,315
7/02	744	200	944	12,252	0	0	0	1,322	14,518
7/03	317	124	441	19,212	0	0	0	4,681	24,334
7/04	348	0	348	13,068	0	0	0	1,361	14,777
7/05	264	148	413	5,109	0	0	0	1,806	7,327
7/06	460	0	460	10,164	0	0	0	1,611	12,235
7/07	67	0	67	9,533	0	0	0	610	10,210
7/08	87	0	87	12,424	0	0	0	796	13,307
7/09	0	0	0	10,819	0	0	0	465	11,284
7/10	224	0	224	6,253	0	0	0	929	7,406
7/11	67	0	67	1,873	0	0	0	278	2,219
7/12	47	17	64	758	0	30	0	486	1,338
7/13	30	11	40	480	0	19	0	308	847
7/14	32	0	32	730	0	0	0	407	1,169
7/15	52	0	52	1,190	0	0	0	663	1,905
7/16	36	0	36	3,243	0	0	0	537	3,815

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	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
7/17	37	0	37	3,340	0	0	0	553	3,930
7/18	0	0	0	617	0	0	0	1,377	1,994
7/19	0	0	0	0	2,916	0	0	573	3,489
7/20	0	0	0	0	3,685	0	0	71	3,755
7/21	120	72	192	0	2,411	0	66	183	2,852
7/22	437	0	437	0	2,031	0	0	286	2,755
7/23	53	0	53	0	831	102	0	1,464	2,451
7/24	58	0	58	0	903	111	0	1,590	2,661
7/25	70	0	70	0	1,097	135	0	1,932	3,235
7/26	0	55	55	0	711	208	0	3,596	4,570
7/27	0	0	0	0	1,484	0	0	3,315	4,799
7/28	0	0	0	0	1,006	135	39	3,193	4,373
7/29	0	0	0	0	1,857	0	0	2,223	4,080
7/30	0	0	0	0	2,308	0	215	1,293	3,816
7/31	0	0	0	0	2,595	0	0	1,657	4,253
8/01	0	0	0	0	4,118	87	90	605	4,900
8/02	0	0	0	0	5,961	126	130	876	7,093
8/03	0	0	0	0	5,054	0	123	351	5,528
8/04	84	0	84	0	1,375	0	138	1,967	3,565
8/05	0	0	0	0	1,635	71	178	1,267	3,151
8/06	0	0	0	0	666	0	267	1,140	2,074
8/07	0	0	0	0	1,004	0	403	1,718	3,124
8/08	0	0	0	0	4,672	0	298	483	5,453
8/09	0	0	0	0	1,576	0	115	871	2,561
8/10	0	0	0	0	1,542	0	112	852	2,506
8/11	0	0	0	0	1,962	0	354	796	3,111
8/12	0	0	0	0	1,790	0	574	539	2,903
8/13	0	0	0	0	596	0	334	941	1,871
8/14	0	0	0	0	304	0	35	851	1,190
8/15	0	0	0	0	536	0	62	1,503	2,101
8/16	0	0	0	0	2,673	0	293	1,184	4,150
8/17	0	0	0	0	1,861	0	204	824	2,889
8/18	0	0	0	0	3,524	0	334	595	4,453
8/19	0	0	0	0	634	0	205	1,468	2,307
8/20	0	0	0	0	28	0	165	1,613	1,806
8/21	0	0	0	0	181	0	513	864	1,558
8/22	0	0	0	0	3,289	0	383	285	3,957
8/23	0	0	0	0	1,481	33	82	5,236	6,833
8/24	0	0	0	0	1,470	33	82	5,196	6,780
8/25	0	0	0	0	2,464	0	988	705	4,157
8/26	0	0	0	0	582	0	452	2,312	3,346
8/27	0	0	0	0	392	0	1,057	1,538	2,987
8/28	0	0	0	0	635	0	866	1,044	2,545
8/29	0	0	0	0	576	0	242	857	1,674
8/30	0	0	0	0	177	0	120	1,905	2,203
8/31	0	0	0	0	694	0	616	266	1,575

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	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
9/01	0	0	0	0	439	0	175	1,277	1,891
9/02	0	0	0	0	1,086	0	174	1,296	2,556
9/03	0	0	0	0	708	0	116	804	1,629
9/04	0	0	0	0	408	0	134	1,192	1,734
9/05	0	0	0	0	20	0	9	268	296
9/06	0	0	0	0	34	0	28	562	625
9/07	0	0	0	0	3	0	2	59	64
Total	12,983	2,836	15,814	207,029	79,985	1,090	10,773	95,178	409,866

[a] Chinook salmon > 655 mm.

[b] Chinook salmon ≤ 655 mm.

Appendix F2.–Proportions by species, of daily total passage (both banks combined) for sectors 1 and 2 of strata 3 of the left bank nearshore region generated by the DIDSON, at the Pilot Station sonar project on the Yukon River, 2011.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
6/01	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/02	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/03	ND	ND	ND	ND	ND	ND	ND	ND	ND
6/04	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.17
6/05	0.28	0.00	0.28	0.00	0.00	0.00	0.00	0.38	0.37
6/06	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.35	0.37
6/07	0.27	0.46	0.33	0.43	0.00	0.00	0.00	0.12	0.30
6/08	0.37	0.58	0.43	0.58	0.00	0.00	0.00	0.16	0.39
6/09	0.38	0.56	0.43	0.45	0.00	0.00	0.00	0.05	0.42
6/10	0.53	0.61	0.54	0.46	0.00	0.00	0.00	0.25	0.46
6/11	0.41	0.00	0.39	0.43	0.00	0.00	0.00	0.37	0.41
6/12	0.32	0.18	0.29	0.30	0.00	0.00	0.00	0.00	0.24
6/13	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.28	0.21
6/14	0.09	0.21	0.16	0.18	0.00	0.00	0.00	0.21	0.20
6/15	0.12	0.31	0.23	0.25	0.00	0.00	0.00	0.30	0.28
6/16	0.18	0.19	0.18	0.15	0.00	0.00	0.00	0.11	0.15
6/17	0.11	0.12	0.11	0.09	0.00	0.00	0.00	0.12	0.09
6/18	0.11	0.12	0.11	0.10	0.00	0.00	0.00	0.12	0.10
6/19	0.08	0.20	0.09	0.11	0.00	0.00	0.00	0.06	0.11
6/20	0.06	0.09	0.07	0.04	0.00	0.00	0.00	0.02	0.05
6/21	0.06	0.10	0.07	0.05	0.00	0.00	0.00	0.03	0.05
6/22	0.19	0.16	0.19	0.11	0.00	0.00	0.00	0.12	0.12
6/23	0.11	0.11	0.11	0.06	0.00	0.00	0.00	0.00	0.07
6/24	0.03	0.06	0.03	0.03	0.00	0.00	0.00	0.00	0.03
6/25	0.02	0.01	0.02	0.02	0.00	0.00	0.00	0.03	0.02
6/26	0.01	0.02	0.01	0.02	0.00	0.00	0.00	0.03	0.02
6/27	0.03	0.04	0.03	0.02	0.00	0.00	0.00	0.01	0.02
6/28	0.06	0.07	0.07	0.03	0.00	0.00	0.00	0.01	0.03
6/29	0.06	0.00	0.06	0.04	0.00	0.00	0.00	0.00	0.04
6/30	0.04	0.05	0.04	0.02	0.00	0.00	0.00	0.01	0.02
7/01	0.11	0.13	0.11	0.08	0.00	0.00	0.00	0.13	0.08
7/02	0.18	0.20	0.18	0.11	0.00	0.00	0.00	0.18	0.12
7/03	0.09	0.11	0.10	0.10	0.00	0.00	0.00	0.21	0.12
7/04	0.11	0.00	0.11	0.11	0.00	0.00	0.00	0.12	0.11
7/05	0.13	0.10	0.12	0.09	0.00	0.00	0.00	0.15	0.10
7/06	0.26	0.00	0.24	0.20	0.00	0.00	0.00	0.14	0.19
7/07	0.08	0.00	0.08	0.20	0.00	0.00	0.00	0.06	0.17
7/08	0.11	0.00	0.10	0.27	0.00	0.00	0.00	0.09	0.24
7/09	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.09	0.20
7/10	0.39	0.00	0.34	0.28	0.00	0.00	0.00	0.10	0.23
7/11	0.22	0.00	0.18	0.14	0.00	0.00	0.00	0.04	0.11
7/12	0.06	0.09	0.06	0.07	0.00	0.16	0.00	0.06	0.07
7/13	0.05	0.08	0.05	0.06	0.00	0.16	0.00	0.05	0.06
7/14	0.11	0.00	0.11	0.08	0.00	0.00	0.00	0.11	0.09
7/15	0.12	0.00	0.12	0.09	0.00	0.00	0.00	0.12	0.10
7/16	0.15	0.00	0.12	0.11	0.00	0.00	0.00	0.10	0.11

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Appendix F2.–Page 2 of 3.

	Chinook			Chum					
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other	Total
7/17	0.21	0.00	0.15	0.12	0.00	0.00	0.00	0.12	0.12
7/18	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.14	0.09
7/19	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.11	0.20
7/20	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.09	0.18
7/21	0.20	0.30	0.23	0.00	0.16	0.00	0.30	0.09	0.16
7/22	0.38	0.00	0.36	0.00	0.21	0.00	0.00	0.11	0.21
7/23	0.42	0.00	0.42	0.00	0.18	0.22	0.00	0.29	0.24
7/24	0.48	0.00	0.48	0.00	0.26	0.27	0.00	0.36	0.31
7/25	0.52	0.00	0.52	0.00	0.30	0.33	0.00	0.42	0.37
7/26	0.00	0.56	0.56	0.00	0.28	0.56	0.00	0.37	0.36
7/27	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.31	0.29
7/28	0.00	0.00	0.00	0.00	0.12	0.34	0.35	0.24	0.20
7/29	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.32	0.25
7/30	0.00	0.00	0.00	0.00	0.16	0.00	0.16	0.16	0.16
7/31	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.14	0.14
8/01	0.00	0.00	0.00	0.00	0.07	0.13	0.06	0.05	0.07
8/02	0.00	0.00	0.00	0.00	0.07	0.16	0.06	0.05	0.07
8/03	0.00	0.00	0.00	0.00	0.09	0.00	0.05	0.05	0.08
8/04	0.24	0.00	0.24	0.00	0.08	0.00	0.09	0.17	0.12
8/05	0.00	0.00	0.00	0.00	0.13	0.13	0.10	0.14	0.13
8/06	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.11	0.11
8/07	0.00	0.00	0.00	0.00	0.11	0.00	0.11	0.12	0.11
8/08	0.00	0.00	0.00	0.00	0.08	0.00	0.07	0.07	0.08
8/09	0.00	0.00	0.00	0.00	0.07	0.00	0.05	0.07	0.07
8/10	0.00	0.00	0.00	0.00	0.11	0.00	0.08	0.11	0.11
8/11	0.00	0.00	0.00	0.00	0.17	0.00	0.10	0.15	0.15
8/12	0.00	0.00	0.00	0.00	0.12	0.00	0.11	0.10	0.11
8/13	0.00	0.00	0.00	0.00	0.12	0.00	0.10	0.12	0.12
8/14	0.00	0.00	0.00	0.00	0.10	0.00	0.06	0.12	0.11
8/15	0.00	0.00	0.00	0.00	0.09	0.00	0.06	0.13	0.11
8/16	0.00	0.00	0.00	0.00	0.16	0.00	0.08	0.09	0.12
8/17	0.00	0.00	0.00	0.00	0.14	0.00	0.06	0.06	0.10
8/18	0.00	0.00	0.00	0.00	0.10	0.00	0.08	0.06	0.09
8/19	0.00	0.00	0.00	0.00	0.06	0.00	0.05	0.10	0.08
8/20	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.16	0.12
8/21	0.00	0.00	0.00	0.00	0.25	0.00	0.19	0.11	0.14
8/22	0.00	0.00	0.00	0.00	0.16	0.00	0.16	0.01	0.08
8/23	0.00	0.00	0.00	0.00	0.04	0.28	0.01	0.18	0.10
8/24	0.00	0.00	0.00	0.00	0.03	0.28	0.01	0.21	0.09
8/25	0.00	0.00	0.00	0.00	0.12	0.00	0.10	0.10	0.11
8/26	0.00	0.00	0.00	0.00	0.10	0.00	0.07	0.20	0.14
8/27	0.00	0.00	0.00	0.00	0.13	0.00	0.15	0.18	0.16
8/28	0.00	0.00	0.00	0.00	0.18	0.00	0.16	0.14	0.16
8/29	0.00	0.00	0.00	0.00	0.19	0.00	0.09	0.14	0.14
8/30	0.00	0.00	0.00	0.00	0.15	0.00	0.05	0.30	0.22
8/31	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.08	0.14

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Date	Chinook			Chum		Pink	Coho	Other	Total
	Large[a]	Small[b]	Total	Summer	Fall				
9/01	0.00	0.00	0.00	0.00	0.15	0.00	0.07	0.18	0.15
9/02	0.00	0.00	0.00	0.00	0.08	0.00	0.08	0.14	0.10
9/03	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.10	0.06
9/04	0.00	0.00	0.00	0.00	0.10	0.00	0.05	0.12	0.11
9/05	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.03
9/06	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.08	0.07
9/07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Season Total	9.23	5.83	9.93	6.54	6.62	3.02	3.79	12.71	14.15

[a] Chinook salmon > 655 mm.

[b] Chinook salmon ≤ 655 mm.

APPENDIX G: DAILY CUMULATIVE FISH PASSAGE, PROPORTIONS, AND TIMING, BY SPECIES

Appendix G1.–Daily cumulative fish passage proportions and timing by species, at the Pilot Station sonar project on the Yukon River, 2011.

	Chinook			Chum				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other
6/01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6/04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
6/05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
6/06	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02
6/07	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02
6/08	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.02
6/09	0.03	0.04	0.03	0.01	0.00	0.00	0.00	0.02
6/10	0.04	0.05	0.04	0.02	0.00	0.00	0.00	0.03
6/11	0.05	0.05	0.05	0.02	0.00	0.00	0.00	0.03
6/12	0.06	0.06	0.06	0.02	0.00	0.00	0.00	0.03
6/13	0.06	0.06	0.06	0.03	0.00	0.00	0.00	0.04
6/14	0.07	0.08	0.07	0.03	0.00	0.00	0.00	0.04
6/15	0.07	0.10	0.07	0.03	0.00	0.00	0.00	0.05
6/16	0.10	0.11	0.10	0.04	0.00	0.00	0.00	0.06
6/17	0.15	0.14	0.15	0.08	0.00	0.00	0.00	0.06
6/18	0.22	0.18	0.22	0.13	0.00	0.00	0.00	0.06
6/19	**0.26**	0.20	**0.25**	0.16	0.00	0.00	0.00	0.06
6/20	0.28	**0.26**	0.28	0.16	0.00	0.00	0.00	0.06
6/21	0.30	0.32	0.31	0.17	0.00	0.00	0.00	0.07
6/22	0.42	0.39	0.41	**0.26**	0.00	0.00	0.00	0.07
6/23	**0.53**	0.47	**0.52**	0.38	0.00	0.00	0.00	0.07
6/24	0.63	**0.53**	0.61	0.46	0.00	0.00	0.00	0.07
6/25	0.66	0.63	0.65	**0.50**	0.00	0.00	0.00	0.07
6/26	0.67	0.69	0.68	0.51	0.00	0.00	0.00	0.07
6/27	0.68	0.70	0.68	0.52	0.00	0.00	0.00	0.08
6/28	0.68	0.71	0.69	0.53	0.00	0.00	0.00	0.08
6/29	0.70	0.71	0.70	0.53	0.00	0.00	0.00	0.08
6/30	0.74	**0.75**	0.74	0.56	0.00	0.00	0.00	0.09
7/01	**0.77**	0.78	**0.77**	0.59	0.00	0.00	0.00	0.10
7/02	0.81	0.82	0.81	0.65	0.00	0.00	0.00	0.11
7/03	0.84	0.87	0.85	0.74	0.00	0.00	0.00	0.14
7/04	0.87	0.87	0.87	**0.80**	0.00	0.00	0.00	0.15
7/05	0.90	0.94	0.90	0.83	0.00	0.00	0.00	0.17
7/06	0.91	0.94	0.92	0.85	0.00	0.00	0.00	0.19
7/07	0.92	0.95	0.93	0.88	0.00	0.00	0.00	0.20
7/08	0.93	0.95	0.93	0.90	0.00	0.00	0.00	0.21
7/09	0.93	0.95	0.94	0.93	0.00	0.00	0.00	0.22
7/10	0.94	0.95	0.94	0.94	0.00	0.03	0.00	0.23
7/11	0.94	0.96	0.94	0.95	0.00	0.05	0.00	0.24
7/12	0.95	0.96	0.95	0.95	0.00	0.08	0.00	**0.26**
7/13	0.96	0.97	0.96	0.96	0.00	0.10	0.00	0.26
7/14	0.96	0.97	0.96	0.96	0.00	0.10	0.00	0.27
7/15	0.96	0.97	0.96	0.97	0.00	0.10	0.00	0.28
7/16	0.96	0.97	0.97	0.98	0.00	0.10	0.00	0.29

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Appendix G1.–Page 2 of 3.

	Chinook			Chum				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other
7/17	0.97	0.98	0.97	0.99	0.00	0.10	0.00	0.29
7/18	0.97	0.98	0.97	1.00	0.00	0.10	0.00	0.31
7/19	0.97	0.98	0.97	1.00	0.02	0.17	0.00	0.31
7/20	0.97	0.98	0.97	1.00	0.04	0.17	0.00	0.32
7/21	0.98	0.99	0.98	1.00	0.06	0.17	0.00	0.32
7/22	0.99	0.99	0.99	1.00	0.07	0.18	0.00	0.32
7/23	0.99	0.99	0.99	1.00	0.08	**0.26**	0.00	0.33
7/24	0.99	0.99	0.99	1.00	0.08	0.32	0.00	0.34
7/25	0.99	0.99	0.99	1.00	0.09	0.38	0.00	0.34
7/26	0.99	0.99	0.99	1.00	0.09	0.44	0.00	0.36
7/27	0.99	0.99	0.99	1.00	0.10	0.44	0.00	0.37
7/28	0.99	0.99	0.99	1.00	0.11	**0.50**	0.00	0.39
7/29	0.99	0.99	0.99	1.00	0.12	0.50	0.00	0.40
7/30	0.99	0.99	0.99	1.00	0.14	0.50	0.01	0.41
7/31	0.99	1.00	1.00	1.00	0.16	0.54	0.01	0.43
8/01	0.99	1.00	1.00	1.00	0.24	0.64	0.03	0.45
8/02	0.99	1.00	1.00	1.00	**0.35**	**0.77**	0.04	0.47
8/03	0.99	1.00	1.00	1.00	0.42	0.82	0.06	0.48
8/04	1.00	1.00	1.00	1.00	0.45	0.82	0.07	**0.50**
8/05	1.00	1.00	1.00	1.00	0.46	0.90	0.09	0.51
8/06	1.00	1.00	1.00	1.00	0.47	0.91	0.11	0.53
8/07	1.00	1.00	1.00	1.00	0.48	0.93	0.14	0.55
8/08	1.00	1.00	1.00	1.00	**0.56**	0.93	0.17	0.56
8/09	1.00	1.00	1.00	1.00	0.58	0.93	0.19	0.57
8/10	1.00	1.00	1.00	1.00	0.60	0.93	0.20	0.59
8/11	1.00	1.00	1.00	1.00	0.62	0.93	0.23	0.59
8/12	1.00	1.00	1.00	1.00	0.64	0.96	**0.27**	0.60
8/13	1.00	1.00	1.00	1.00	0.64	0.96	0.30	0.61
8/14	1.00	1.00	1.00	1.00	0.65	0.96	0.30	0.62
8/15	1.00	1.00	1.00	1.00	0.66	0.96	0.31	0.64
8/16	1.00	1.00	1.00	1.00	0.68	0.96	0.34	0.66
8/17	1.00	1.00	1.00	1.00	0.70	0.96	0.37	0.68
8/18	1.00	1.00	1.00	1.00	0.74	0.96	0.41	0.69
8/19	1.00	1.00	1.00	1.00	**0.76**	0.96	0.44	0.71
8/20	1.00	1.00	1.00	1.00	0.76	0.96	0.46	0.73
8/21	1.00	1.00	1.00	1.00	0.76	0.96	0.48	0.74
8/22	1.00	1.00	1.00	1.00	0.79	0.96	**0.50**	**0.77**
8/23	1.00	1.00	1.00	1.00	0.84	0.98	0.55	0.81
8/24	1.00	1.00	1.00	1.00	0.89	1.00	0.60	0.85
8/25	1.00	1.00	1.00	1.00	0.92	1.00	0.67	0.86
8/26	1.00	1.00	1.00	1.00	0.93	1.00	0.73	0.88
8/27	1.00	1.00	1.00	1.00	0.93	1.00	**0.78**	0.89
8/28	1.00	1.00	1.00	1.00	0.94	1.00	0.83	0.90
8/29	1.00	1.00	1.00	1.00	0.94	1.00	0.85	0.91
8/30	1.00	1.00	1.00	1.00	0.94	1.00	0.87	0.92
8/31	1.00	1.00	1.00	1.00	0.95	1.00	0.90	0.92

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	Chinook			Chum				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Other
9/01	1.00	1.00	1.00	1.00	0.95	1.00	0.92	0.93
9/02	1.00	1.00	1.00	1.00	0.97	1.00	0.94	0.95
9/03	1.00	1.00	1.00	1.00	0.99	1.00	0.96	0.96
9/04	1.00	1.00	1.00	1.00	0.99	1.00	0.98	0.97
9/05	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98
9/06	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
9/07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: The 25th, 50th, and 75th percentiles are in bold.

[a] Chinook salmon > 655 mm.

[b] Chinook salmon ≤ 655 mm.